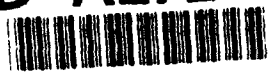


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— COMMITTED TO PROTECTION OF THE ENVIRONMENT —

COMPREHENSIVE MONITORING PROGRAM

Contract Number DAAA15-87-0095

ANNUAL GROUND WATER REPORT FOR 1988
JUNE 1989

FINAL REPORT

Volume I

R.L. STOLLAR & ASSOCIATES, INC.

Harding Lawson Associates
Ebasco Services Incorporated
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**ANNUAL GROUND WATER REPORT FOR 1988
JUNE 1989**

FINAL REPORT

Volume I

Prepared by:

**R. L. STOLLAR & ASSOCIATES INC.
HARDING LAWSON ASSOCIATES
EBASCO SERVICES INC.
DATACHEM, INC.
ENSECO-CAL LAB
MIDWEST RESEARCH INSTITUTE**

Prepared for:

**PROGRAM MANAGER FOR
ROCKY MOUNTAIN ARSENAL**

Approved For	
By	A
Date	
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ACRONYMS AND ABBREVIATIONS

ac-ft	acre-feet
AL	A sand zone - lower
ALDRN	Aldrin
AM	A sand zone - middle
ARAR	Applicable or Relevant and Appropriate Requirement
As	Arsenic
AS	A sand zone - channel
AU	A sand zone - upper
BGL	Below ground level
BTZ	Benzothiazole
CCl ₄	Carbon tetrachloride
CDH	Colorado Department of Health
cfs	cubic feet per second
C ₆ H ₆	Benzene
CH ₂ Cl ₂	Methylene chloride
Cl	Chloride
ClC ₆ H ₅	Chlorobenzene
CHCl ₃	Chloroform
CMP	Comprehensive Monitoring Program
cm/sec	centimeters per second
CPMS	p-Chlorophenylmethyl sulfide
CPMSO	p-Chlorophenylmethyl sulfoxide
CPMSO ₂	p-Chlorophenylmethyl sulfone
CRL	Certified Reporting Limit
CWP	Composite Well Program
CWA	Clean Water Act
DBCP	Dibromochloropropane
11DCE	1,1-Dichloroethene
12DCE	Trans 1,2-dichloroethene
12DCLE	1,2-Dichloroethane
DCPD	Dicyclopentadiene
DIMP	Diisopropylmethyl phosphonate
DITH	Dithiane

ACRONYMS AND ABBREVIATIONS (continued)

DLDRN	Dieldrin
DMDS	Dimethyldisulfide
DMMP	Dimethylmethyl phosphonate
ENDRN	Endrin
EPA	U.S. Environmental Protection Agency
ESE	Environmental Science and Engineering, Inc.
ETC ₆ H ₅	Ethylbenzene
F	Fluoride
FCP	First Creek Paleochannel
FS	Feasibility Study
ft	feet
ft/d	feet per day
ft ³	cubic feet
FY87	Fiscal Year 1987
FY88	Fiscal Year 1988
FY89	Fiscal Year 1989
gal/ft ²	gallons per square foot
GC/MS	gas chromatography/mass spectrometry
gpd/ft	gallons per day per foot
gpd/ft ²	gallons per day per square foot
GT	greater than
HLA	Harding Lawson Associates
ICS	Irondale Containment System
ISODR	Isodrin
ISP	Initial Screening Program
LA	Lignite A
LB	Lignite B
LC	Lignite C
LD	Lignite D
LT	less than
MEC ₆ H ₅	Toluene
mi	mile
mg/l	milligrams per liter
MKE	Morrison-Knudsen Engineers, Inc.
msl	mean sea level

ACRONYMS AND ABBREVIATIONS (continued)

NBCS	North Boundary Containment System
NWBCS	Northwest Boundary Containment System
NWBP	Northwest Boundary Paleochannel
OCP	organochlorine pesticide
OXAT	Oxathiane
PCE	Tetrachloroethene
p,p'-DDE	Dichlorodiphenylethane
p,p'-DDT	Dichlorodiphenyltrichloroethane
QA/QC	Quality Assurance/Quality Control
RI	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
RIC	RMA Information Center
RLSA	R. L. Stollar & Associates, Inc.
RMA	Rocky Mountain Arsenal
RMACCPMT	Rocky Mountain Arsenal Contamination Control Program Management Team
SACWSD	South Adams County Water and Sanitation District
SARIN	Isopropylmethane fluorophosphonate (nerve agent), also known as GB
SCC	Shell Chemical Company
SDWA	Safe Drinking Water Act
SIA	Stapleton International Airport
sq mi	square mile
SW/GW	surface water/ground water
T	transmissivity
TCE	Trichloroethlyene
111TCE	1,1,1-Trichloroethane
112TCE	1,1,2-Trichloroethane
TCLEE	Tetrachloroethlyene
TDS	Total Dissolved Solids

ACRONYMS AND ABBREVIATIONS (continued)

TMP	Transitional Monitoring Program (of the CMP)
TRCLE	Trichloroethylene
1U	number one upper zone in the Denver Fm
µg/l	micrograms per liter, nearly equivalent to parts per billion (ppb)
UFS	Unconfined Flow System
UNC	Unconfined
USATHAMA	U.S. Army Toxic and Hazardous Materials Agency
USCS	Unified Soil Classification System
USGS	United States Geological Survey
VC	volcaniclastic interval
VCE	equivalent zone to VC
VOA	volatile organic aromatics
VOH	volatile organohalogens
WES	U.S. Army Corps of Engineers Waterways Experiment Station
WRI	Water Remedial Investigation

1.0 INTRODUCTION

1.1 Site Background

Rocky Mountain Arsenal (RMA), which occupies approximately 27 square miles (sq mi) in Adams County, Colorado, is located about 9 miles (mi) northeast of downtown Denver (Figure 1.1-1). RMA was established by the U.S. Army (the Army) in 1942 for producing, handling, and dismantling of chemical and incendiary munitions. Industrial chemicals were also manufactured at RMA by several lessees from 1947 to 1982.

Disposal practices at RMA included routine discharge of industrial waste effluents to unlined and lined evaporation basins and the burial of solid wastes at various locations. Unintentional spills of raw materials, process intermediates and end products also occurred within the manufacturing complexes at RMA.

1.2 Nature and Extent of Problem

As early as 1951 a link was suspected between waterfowl mortality at RMA and insecticide contamination of the lakes located there. In 1954 and 1955, farmers using well water for irrigation northwest of RMA reported severe crop losses (HEW Public Health Service, 1965). In 1974, two contaminants -- diisopropylmethyl phosphonate (DIMP), a manufacturing by-product of the nerve agent isopropylmethane fluorophosphonate (Sarin, or GB), and dicyclopentadiene (DCPD), a chemical used in insecticide production -- were detected in off-post surface water. Since 1978, dibromochloropropane (DBCP), a nematocide shipped from RMA by rail from 1970 to 1975, has been detected in off-post ground water.

Contaminants were introduced to the RMA environment primarily by the burial or surface disposal of solid wastes, discharge of wastewaters to basins, and leakage of wastewaters and industrial fluids from chemical and sanitary sewer systems. Munitions were destroyed and disposed of in trenches. Wastewaters generated by the Army and private industry in the South Plants and North Plants area were discharged to a series of unlined evaporation and holding basins (Basins A, B, C, D and E), and to asphalt-lined Basin F at various times throughout the history of RMA operations (Figure 1.2-1).

The primary areas that may be contributing to ground-water contamination at RMA include: former manufacturing facilities, waste storage basins (Basins A, B, C, D, E and F), solid waste

disposal areas, chemical sewer system, and locations within the rail classification yard (see Figure 1.2-1).

1.3 Summary of Previous Ground-water Monitoring Efforts

As a result of the detection of contaminants off-site, the State of Colorado issued three administrative orders commonly called the cease and desist orders of 1975. In response to the cease and desist orders, the Army initiated a regional sampling and hydrogeologic surveillance program requiring the quarterly collection and analysis of samples from over 100 on and off-post wells and surface-water stations. This program was carried out under the direction of the RMA Contamination Control Program which had been established in 1974 to ensure compliance with federal and state environmental laws. The objectives of this program were to evaluate the nature and extent of contamination and to develop response actions to control contaminant migration. Potential and actual contamination sources were assessed, and contaminant migration pathways were evaluated. To minimize off-post discharge of RMA contaminants via ground water, three boundary containment systems were constructed, one each at the northern, western, and northwestern boundaries of RMA. All three systems are currently in operation to intercept and treat contaminated ground water and to recharge the treated water. Figure 1.3-1 shows the location of the ground-water control systems currently in operation at RMA and the contaminant distribution patterns of major contaminant groups in the alluvial ground-water system.

From 1975 to the present, numerous ground-water monitoring programs have been conducted at RMA. Following issuance of the cease and desist orders, the Army established the 360 Degree Monitoring Program to monitor regional ground and surface water. The Army designed and implemented a boundary system monitoring program to support the operation of the boundary control systems.

In 1984 the Army awarded a multi-year task order contract to initiate a Remedial Investigation/Feasibility Study (RI/FS) at RMA. Two consecutive regional ground-water tasks were awarded under this contract (Tasks 4 and 44). The purpose of these tasks was to investigate the nature and extent of RMA ground-water contamination and to continue long-term ground-water monitoring initiated under the 360 Degree Program. In addition, Task 25 (Boundary Control Systems Monitoring) was awarded to continue ground-water monitoring in the vicinity of the boundary control systems. In 1987 the Army separated both the long-term ground-water monitoring and the boundary systems monitoring from the RI/FS program. These activities are now included under the ground-water element of the Comprehensive Monitoring Program (CMP).

1.4 Overview of Current Ground-Water Monitoring

The Comprehensive Monitoring Program (CMP) is designed to provide both continual and long-term monitoring of ground water, surface water, air and biota. Each environmental medium is being monitored within a separate program element. Each element has detailed objectives, outlined in respective technical plans, which establish monitoring guidelines, analytical parameters, and sampling protocol and strategies. All four elements have the common objectives of providing a database that is of USATHAMA quality. An annual report for each element discusses the results of the year's monitoring effort.

A transitional round of ground-water monitoring activities was initiated in November 1987 immediately following award of the CMP contract to provide continuity with the previous regional and boundary systems monitoring programs conducted under the RI/FS contract. This sampling program, the Transition Monitoring Program (TMP), was initiated prior to completing the design of the long-term monitoring well network. TMP network design details are presented in the Letter Technical Plan for the TMP (Stollar, 1987). The design strategy of the long-term ground-water monitoring network was developed after reviewing data generated during previous monitoring programs, including data from RI/FS Tasks 4, 25 and 44. It is discussed in the CMP Technical Plan.

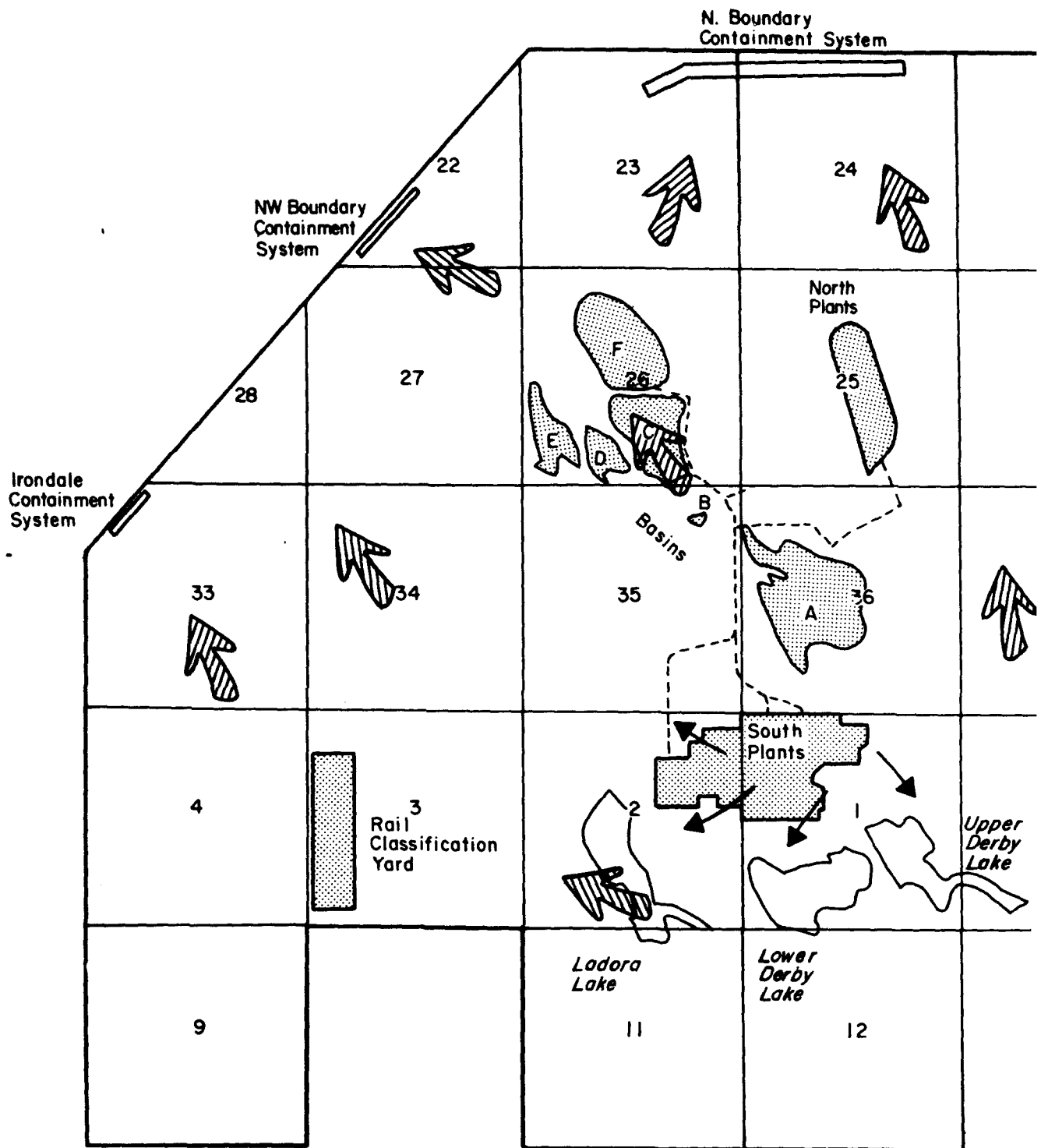
The objectives of the CMP ground-water element are threefold:

- Maintain a regional ground-water monitoring program for regulatory database maintenance and RI/FS verification purposes;
- Maintain project ground-water monitoring programs for regulatory database maintenance, RI/FS verification, and system operational purposes; and
- Monitor ground-water quality and hydrology to assess changes in the rate and extent of contaminant migration and the distribution of contaminants both in on-post and off-post areas.

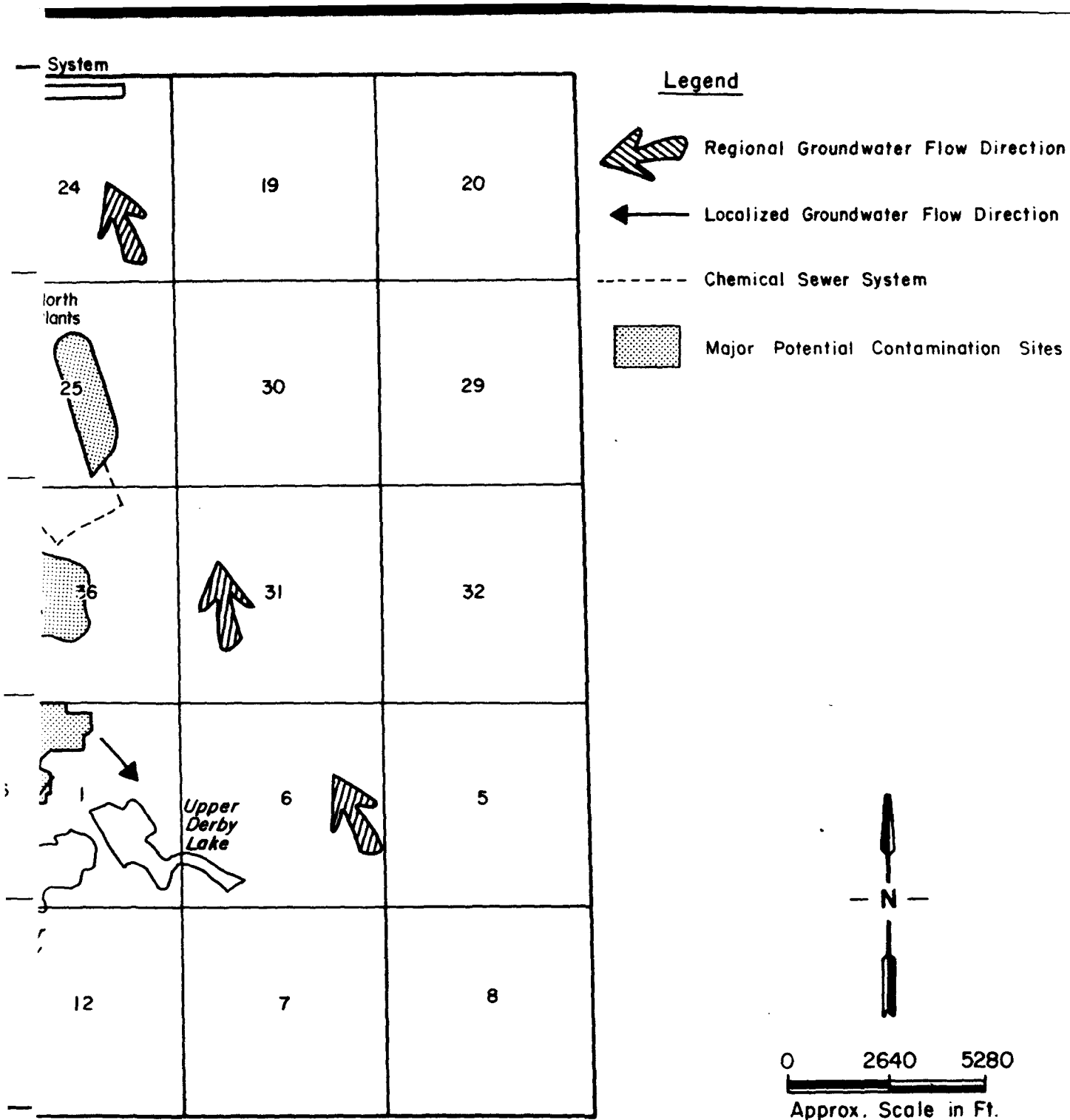
The ground-water element of the CMP includes water-level and water-quality monitoring at three scales, each at specified frequencies: (1) a regional scale which consists of the annual monitoring of selected wells; (2) a localized scale which consists of semiannual monitoring in specific areas requiring further evaluation of contaminant flow patterns; and (3) a localized scale which consists

of quarterly monitoring in support of ongoing remedial/response actions and/or substantive compliance with applicable regulatory requirements.

This report presents data collected during Fiscal Year 1988 (FY88). The annual TMP sampling round began in November 1987 and continued through February 1988; it is referred to as the winter 1987/88 event. The final sampling round conducted as part of Task 25, the Boundary Control Systems Assessment Remedial Investigation (RI), was concurrent with the initial TMP sampling round. Because sampling was concurrent, data from both Task 25 and the TMP are presented in this report. The quarterly sampling round scheduled for August 1988 was conducted in July and August of 1988 (referred to as the summer 1988 event). The semiannual sampling round began in May 1988 and continued through June 1988, and is referred to as the spring 1988 event.



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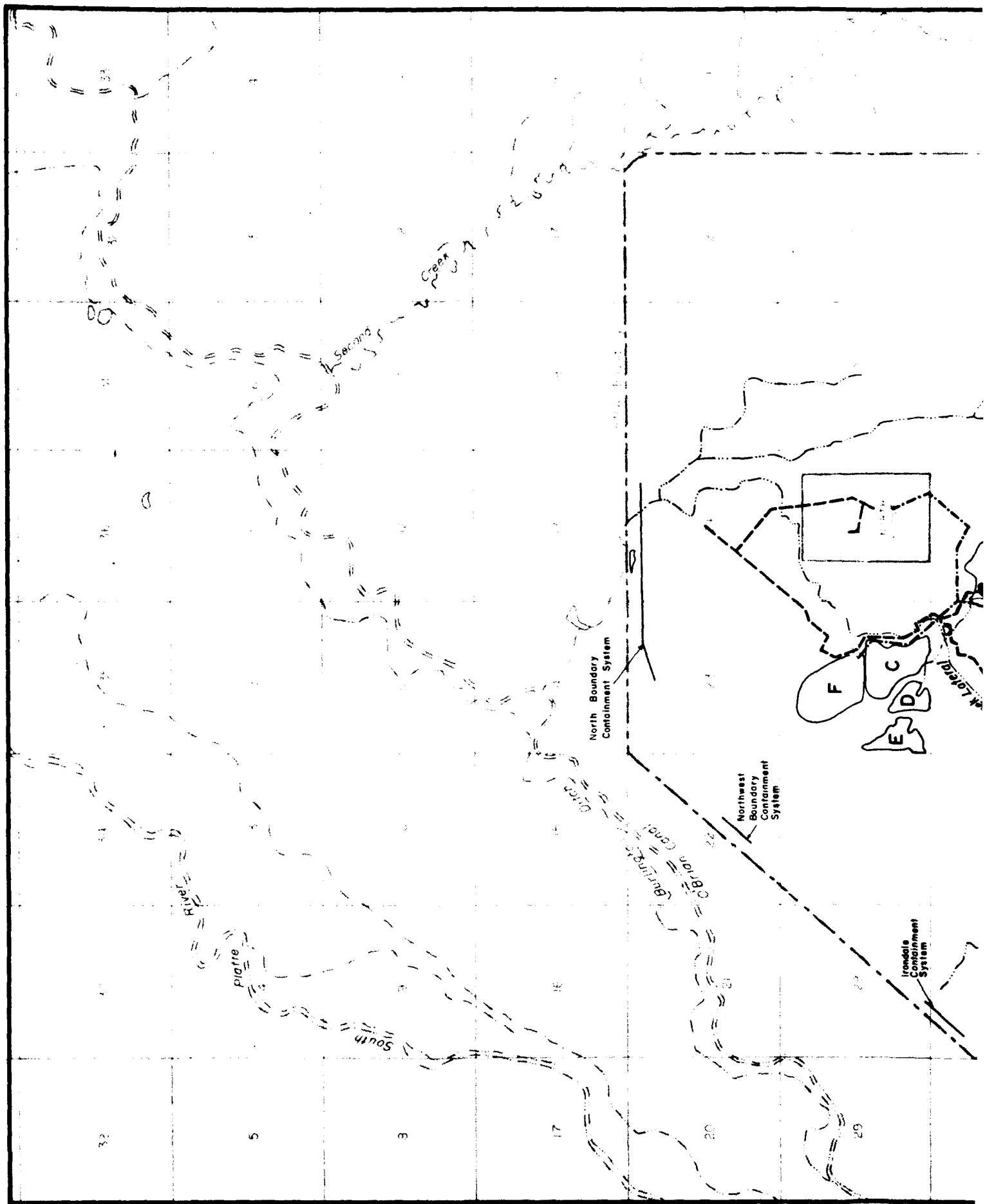


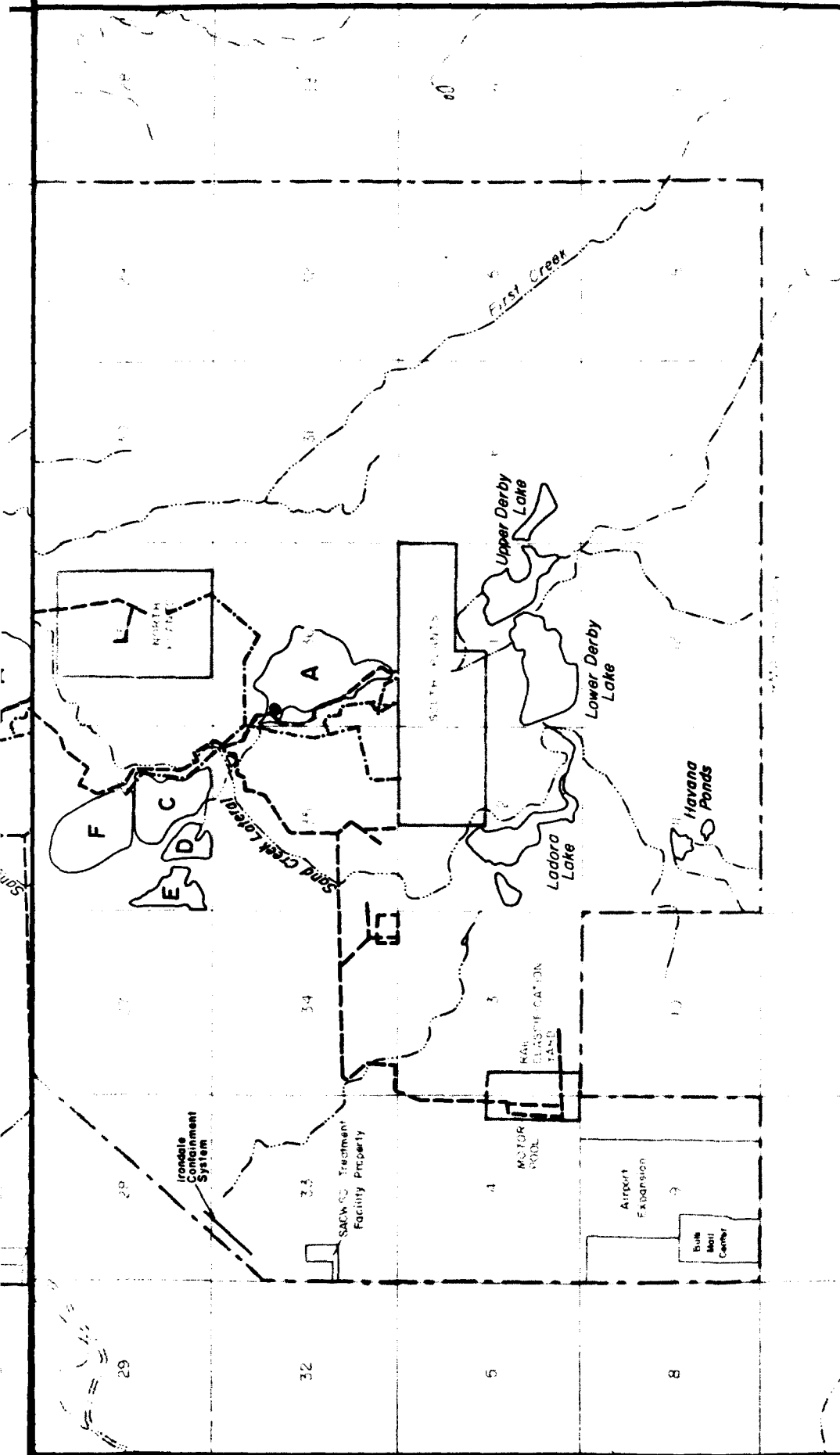
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Program Manager's Office for
Rocky Mountain Arsenal Cleanup
Aberdeen Proving Ground, Maryland
Drafted: 12/11/87

FIGURE 1

RMA Base Map Showing Major Potential
Contamination Sites, Cultural Features,
Boundary Containment Systems, and
Dominant Alluvial Groundwater Flow
Directions Source: HLA, 1987
Prepared by: R.L. Stollar and Associates, Inc.








Prepared for:

Program Manager's Office for
 Rocky Mountain Arsenal
 Aberdeen Proving Ground, Maryland

FIGURE 1.2-1

Location of Major Potential Contamination Sites, Lakes and Containment Systems
 CMP Ground - Water Monitoring Annual Report
 Prepared by: R.L. Stollar & Associates Inc.
 Harding Lawson Associates

EXPLANATION

-  Waste Containment Basin
-  Chemical Sewer System
-  Sanitary Sewer System

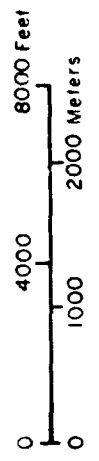
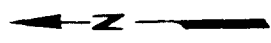


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2.0 HYDROGEOLOGIC SETTING

This section provides a description of the geologic and hydrogeologic characteristics in the RMA study area. For a more thorough discussion of this subject, refer to the Water Remedial Investigation Report (Ebasco, 1989), which presents a comprehensive interpretation of hydrologic conditions at RMA.

2.1 Geology

RMA is located within the Denver Basin, a structural depression that extends from Colorado into Western Nebraska, Kansas, and Eastern Wyoming. The eastern flank of the basin dips gently, but its western flank dips steeply, exposing several sedimentary units in outcrop along the Colorado Front Range. RMA is located along the structural axis of the basin, where the area's geologic strata dips to the Southeast at less than one degree.

Strata in the Denver Basin containing usable quantities of potable water are the Fox Hills Sandstone, Laramie Formation, Arapahoe Formation, Denver Formation, and Dawson Arkose (Figure 2.1-1). However, the Dawson Arkose occurs only in the southern part of the Denver Basin and is not present at RMA. Unconsolidated alluvial and eolian deposits are at the land surface throughout most of RMA. Pierre Shale, which underlies these strata, forms a thick, relatively impermeable bottom for the regional aquifer system. The Pierre Shale is approximately 1,500 ft below the surface at RMA.

The Denver Basin was downwarped during Late Cretaceous and early Tertiary periods; the fluvial sands and clays of the Arapahoe and Denver Formations were also deposited during this time. Additional sediments were deposited in the basin throughout the Tertiary period. Regional uplift and erosion later removed most of these sediments as well as part of the Denver Formation. The resulting erosional surface varies from 30 to 70 feet (ft) elevation within the RMA study area. Sediments deposited on this erosional surface consist of unconsolidated alluvial gravel, sand, and clay, as well as eolian (windblown) material. RMA Sections 25 and 36 have volcanic ash beds and erosional remnants of volcanoclastic flows within a matrix of unconsolidated gravel, sand, silt and clay (Lindvall, 1982).

The Denver Formation and unconsolidated surficial deposits are the two major stratigraphic sequences beneath RMA that are addressed by this report. Surficial deposits on the bedrock surface are collectively referred to as the alluvium, although both alluvial and eolian materials exist in this interval.

2.1.1 Alluvium

Alluvial and eolian sediments reach local thicknesses of 130 ft. However, thickness typically is much less, generally less than 50 ft. Areas with less than 20 ft of alluvium are common.

Seven distinct alluvial units have been identified at RMA. These include, from oldest to youngest, the Verdos, Slocum, Louviers, Broadway, Loess/Eolian, Piney Creek and Post Piney Creek Alluvium (Figure 2.1-2). Older alluvial units, located along the South Platte River, generally consist of coarse-grained sand and gravel. Eolian deposits and younger alluvial units are composed of finer-grained materials than are older alluvial units. Eolian materials are the predominant materials exposed at land surface and blanket other identified alluvial units, as shown in Figure 2.1-3. Recent investigation reports (Morrison-Knudsen, 1988b; Ebasco, 1989) provide extensive discussions of alluvium.

2.1.2 Denver Formation

The Denver Formation, 200 to 400 ft thick at RMA, consists of interbedded claystones, siltstones, sandstones, and organic-rich (lignitic) intervals. Water-bearing layers of sandstone and siltstone occur in irregular beds that are dispersed within thick sequences of relatively impermeable material. Individual sandstone layers commonly are lens-shaped and range in thickness from a few inches to as much as 50 ft. Reliable correlation of individual sandstone layers between wells is generally good in areas such as South Plants and Basin A, where a thick lignite bed is present and provides a recognizable horizon marker. Correlations through other areas of RMA are more tenuous. Lignitic beds typically vary in thickness from 0 to 13 ft, are more continuous laterally than are sandstone layers, and commonly are fractured. Low permeability volcanoclastic material is present in the upper part of the Denver Formation.

Stratigraphic zones within the Denver Formation have been identified on the basis of relatively continuous lignitic marker beds (Figure 2.1-4). Each zone consists of discontinuous sandstones separated by claystone. The interval of volcanoclastic material is identified as a separate stratigraphic zone. Most of the data available to map the geologic characteristics of each zone are from shallow zone areas. In these shallower zones, sandstone units (which generally trend north to south) vary in thickness from a few inches to more than 50 ft.

Bedding planes in the Denver Formation dip approximately 1° to the Southeast. Because of this, relatively older stratigraphic zones subcrop toward the Northwest. Evidence for folding or faulting in the Denver Formation at RMA is inconclusive.

2.2 Hydrogeology

Ground water occurs at RMA under both confined (under pressure greater than atmospheric) and unconfined (at atmospheric pressure) conditions. Water in bedrock typically is confined, whereas water in unconsolidated surficial deposits typically is unconfined. Water is also unconfined in areas where bedrock units are exposed at land surface and in some areas where overlying unconsolidated deposits are unsaturated.

This section contains a summary of RMA hydrogeology. The unconfined flow system is described first, and the confined flow system is described second.

2.2.1 Unconfined Flow System

The unconfined flow system includes saturated alluvium, eolian deposits, and subcropping parts of the Denver Formation where lithologic data indicate the presence of sandstone or relatively permeable material. In areas where alluvial and eolian deposits are unsaturated, the unconfined flow system consists solely of sandstone and fractured or weathered rock within the shallow parts of the Denver Formation.

Because the hydraulic conductivity of the Denver Formation generally is lower than the hydraulic conductivity of the alluvium, ground-water flow and contaminant transport through unfractured bedrock is assumed to be relatively low compared to flow and transport in either the saturated alluvium or in fractures of the Denver Formation. Differences in hydraulic conductivity of the alluvium and of unconfined parts of the Denver Formation indicate that the lateral and vertical extent of saturated alluvium has a strong influence on flow patterns and the flux of water within the unconfined system.

The unconfined flow system is discussed below in terms of lateral and vertical extent of alluvium, aquifer recharge, aquifer hydraulics and aquifer discharge.

The saturated thickness of the unconfined flow system varies from less than 10 ft to approximately 70 ft. Thickness is greatest in erosional valleys cut into the surface of the Denver Formation, where it typically varies from 20 to 50 ft. These erosional valleys are most prominent northwest

of RMA, in the western tier of RMA, and south of Ladora Lake. The typical thickness beneath Basins A and F and beneath South Plants is 20 ft or less.

Aquifer tests indicate that the storativity of alluvial material within the unconfined flow system ranges from a low of approximately 0.001 for fine-grained materials to a high of approximately 0.1 for coarse-grained deposits (May, 1982; Ebasco, 1989). Hydraulic conductivity (K) in these materials ranges from 10 feet/day (ft/d) to 3,000 ft/d (3.53×10^{-3} centimeters per second (cm/sec) to 1.06 cm/sec).

The regional potentiometric surface of the unconfined flow system has remained relatively unchanged since 1956. However, man-made stresses have caused substantial water table and gradient fluctuations in local areas. Most notably, these stresses include boundary containment systems activities, recharge from surface water (including lakes and waste ponds), and off-post water supply well operations. These local stresses have had a significant influence on contaminant migration.

A discussion of the configuration of the potentiometric surface for the unconfined flow system is provided in Section 4.1. Water-table elevation contours, hydraulic gradients, and ground-water flow directions are illustrated on maps constructed for three CMP FY88 monitoring periods.

Ground water in the unconfined flow system flows northwest across the RMA study area and discharges to the South Platte River. Changes in flow directions may be attributed to spatial variations in hydraulic conductivity of aquifer materials, to surface-water impoundments, and to the boundary containment systems. Rates and volumes of ground water moving along paleochannels generally are higher than rates and volumes in other parts of the unconfined flow system. Hydraulic gradients are variable throughout the study area and range from 0.002 to 0.010.

Alluvial deposits provide the major pathways for contaminant migration in ground water at RMA. Several major contaminant pathways have been identified (Ebasco, 1989), and these pathways were given names in order to simplify and standardize contaminant distribution discussions (Figure 2.2-1). Pathway names were chosen because of proximity to well-known features and do not imply a source-plume relationship.

Sources of recharge to the unconfined flow system in the study area include infiltration of precipitation and irrigation, seepage from surface-water features such as lakes and streams, inflow from subcropping Denver Formation sandstones, and seepage from man-made structures such as

disposal ponds, canals, ditches and buried pipelines. Estimated recharge rates were summarized in the Water Remedial Investigation Report (WRI Report) (Ebasco, 1989).

The principal discharge location for the unconfined flow system in the study area is the South Platte River. However, unconfined flow system discharge does occur at several other locations within the study area. Previous estimates suggest an average discharge volume of 46,500 acre-feet/year (ac-ft/year) (Ebasco, 1989). Surface discharge from the unconfined flow system is known to occur at Ladora Lake, Lake Mary and the Rod and Gun Club Pond. Discharge resulting from evapotranspiration occurs where the water table is within 5 ft of land surface. Discharge also occurs by vertical flow from the unconfined flow system to the Denver Formation. Estimated discharge rates are summarized in the WRI Report (Ebasco, 1989).

2.2.2 Confined Flow System

The confined flow system consists of strata within the Denver Formation where water is under greater than atmospheric pressure. Confined conditions are observed in the Denver Formation within permeable sandstone or lignite that is separated from the permeable material of the unconfined flow system by relatively impermeable shale or claystone. The bottom of the Denver Formation is delineated by 30 to 50 ft of claystone and shale that separates the Denver from the underlying Arapahoe Formation. The Arapahoe Formation underlies RMA approximately 250 to 400 ft below ground surface (May, 1982).

Hydraulic conductivity of the unconfined flow system varies spatially and reflects variations in lithology. Hydraulic conductivity of shale and claystone is low, probably 10^{-2} to 10^{-4} ft/d (3.53×10^{-6} to 3.53×10^{-8} cm/sec). Laboratory tests of unfractured claystone indicate hydraulic conductivity may be as low as 10^{-8} ft/d (3.53×10^{-12} cm/sec) (May et al., 1982). In contrast, hydraulic conductivity for sandstone has been estimated by slug-test analyses to range from 0.03 to 4.0 ft/d (1.06×10^{-5} to 1.41×10^{-3} cm/sec). Values from aquifer tests range from 1.1 to 7.7 ft/d (3.88×10^{-4} to 2.72×10^{-3} cm/sec). Estimates are not available of hydraulic conductivity for fractured lignitic beds. However, flow model analyses indicate that hydraulic conductivity of lignitic beds may be an order of magnitude greater than hydraulic conductivity of sandstone (D.M. Peterson, 1988).

Hydraulic head in the confined flow system decreases with increasing depth at most locations in the vicinity of RMA. Ground water development was negligible prior to 1885. Prior to 1885, head increased with depth in deep aquifers beneath RMA, and hydraulic heads were large enough to permit building flowing wells in the South Platte River Valley. This discovery led to the first

Denver area hydrologic studies and a boom in well building (Robson, 1987, citing Cross et al., 1884). Ground-water withdrawals from 1885 to the present have caused water level declines greater than 300 ft in the Denver area. As a result, the vertical gradient at RMA has changed from upward to generally downward (Robson, 1987).

Hydrogeologic cross sections and potentiometric surfaces for stratigraphic zones of the Denver Formation indicate that there is potential for ground-water flow toward the Northwest as well as downward (Ebensco, 1989). Although cross sections and potentiometric surface maps indicate flow potential, flow rates also depend on hydraulic conductivity. The lower hydraulic conductivity of claystone relative to sandstone probably restricts vertical flow while enhancing lateral flow.

Recharge occurs to the confined flow system by vertical leakage from the overlying unconfined flow system. Leakage rates per unit area of unfractured rock are low, but flow rates probably are enhanced by flow through fractures. Recharge to the Denver Formation also occurs by underflow from areas south and east of RMA. It is also possible that vertical ground-water flow was enhanced at RMA by poorly sealed wells. Wells that have been identified as potentially problematic are being sealed and abandoned. Discharge from the confined flow system occurs by lateral flow into the unconfined flow system where transmissive strata of the Denver Formation subcrop. No production wells at RMA obtain water from the confined flow system.

Table 3.1-1 CMP Water-level Monitoring Network

Section No.	Total Wells	Wells
Unconfined Wells		
1	29	001, 002, 004, 007, 008, 009, 010, 011, 012, 014, 017, 018, 020, 021, 024, 027, 033, 038, 041, 044, 047, 049, 069, 070, 501, 510, 514, 518, 528
2	21	001, 002, 003, 005, 006, 007, 008, 011, 014, 017, 018, 020, 023, 026, 034, 037, 040, 049, 050, 052, 520
3	11	001, 002, 005, 008, 011, 516, 517, 518, 519, 522, 523
4	39	007, 008, 010, 013, 014, 015, 016, 017, 019, 020, 021, 022, 023, 024, 025, 026, 027, 028, 029, 030, 035, 036, 037, 038, 039, 040, 041, 042, 043, 044, 045, 046, 047, 048, 049, 050, 051, 524, 525
6	2	002, 003
7	2	001, 003
8	2	002, 003
9	13	001, 002, 005, 006, 007, 008, 009, 010, 011, 012, 013, 014, 015
11	4	002, 005, 006, 007
12	6	001, 002, 005, 007, 008, 009
19	5	001, 003, 004, 008, 014
22	35	003, 004, 005, 006, 007, 008, 010, 012, 014, 015, 016, 017, 018, 019, 020, 021, 022, 025, 029, 033, 034, 036, 040, 043, 045, 049, 050, 051, 052, 053, 054, 056, 059, 060, 065
23	110	002, 003, 004, 006, 007, 008, 009, 010, 011, 012, 013, 014, 015, 016, 025, 026, 029, 030, 033, 034, 036, 039, 043, 044, 045, 046, 047, 048, 049, 050, 051, 052, 053, 057, 058, 059, 063, 064, 066, 067, 072, 079, 084, 085, 092, 094, 095, 096, 101, 102, 106, 107, 108, 110, 111, 118, 119, 120, 121, 122, 123, 124, 128, 131, 132, 134, 135, 137, 140, 142, 143, 145, 146, 148, 150, 151, 157, 160, 166, 178, 179, 182, 185, 188, 191, 196, 197, 198, 199, 202, 203, 204, 205, 207, 208, 211, 212, 213, 214, 215, 216, 217, 220, 221, 223, 226, 231, 232, 233, 235
24	112	001, 002, 003, 004, 007, 008, 009, 013, 014, 010, 015, 016, 017, 018, 019, 020, 021, 022, 023, 024, 025, 027, 043, 045, 046, 048, 049, 050, 051, 052, 053, 055, 056, 057, 058, 062, 063, 064, 065, 081, 084, 085, 086, 088, 092, 093, 094, 095, 096, 097, 098, 099, 100, 101, 102, 103, 104, 105, 106, 107, 108, 110, 111, 112, 113, 114, 115, 117, 121, 122, 123, 124, 127, 128, 129, 130, 135, 149, 150, 151, 158, 161, 162, 163, 164, 165, 166, 169, 170, 173, 176, 177, 178, 179, 180, 181, 182, 183, 184, 185, 186, 187, 188, 191, 192, 194, 195, 196, 199, 200, 201

Table 3.1-1 (cont'd.)

Section No.	Total Wells	Wells
Unconfined Wells (cont'd.)		
25	16	001, 003, 011, 015, 018, 022, 027, 035, 038, 041, 042, 043, 044, 046, 047, 048
26	42	001, 002, 004, 005, 006, 009, 010, 011, 015, 016, 017, 018, 019, 020, 040, 041, 044, 046, 048, 049, 050, 062, 063, 065, 068, 070, 071, 073, 076, 081, 083, 085, 088, 091, 093, 124, 126, 127, 133, 143, 145, 148
27	60	002, 003, 004, 005, 006, 007, 008, 009, 010, 011, 012, 013, 015, 016, 017, 018, 019, 024, 025, 026, 028, 030, 031, 034, 037, 040, 041, 042, 043, 044, 045, 049, 050, 051, 053, 056, 057, 059, 062, 063, 064, 066, 068, 070, 071, 072, 073, 074, 075, 076, 077, 078, 079, 080, 081, 082, 083, 084, 085, 086
28	22	002, 003, 004, 005, 006, 007, 008, 009, 011, 012, 013, 014, 015, 018, 020, 021, 022, 023, 024, 027, 503, 513
30	3	001, 002, 009
31	3	003, 005, 009
32	1	001
33	62	001, 002, 014, 017, 018, 019, 020, 021, 022, 023, 024, 025, 030, 033, 039, 048, 049, 050, 051, 052, 053, 054, 060, 061, 062, 063, 064, 065, 066, 067, 068, 069, 070, 071, 072, 073, 074, 075, 076, 077, 078, 079, 500, 501, 502, 505, 506, 507, 509, 510, 511, 512, 514, 533, 534, 576, 577, 579, 580, 581, 582, 583
34	6	001, 002, 005, 008, 009, 515
35	25	006, 007, 013, 018, 020, 023, 025, 026, 031, 034, 037, 040, 047, 048, 052, 053, 058, 061, 065, 069, 077, 079, 081, 087, 088
36	40	001, 013, 017, 050, 054, 056, 060, 063, 065, 067, 069, 073, 074, 075, 076, 077, 081, 082, 084, 085, 087, 089, 090, 093, 103, 109, 112, 123, 128, 134, 135, 137, 139, 141, 142, 145, 146, 177, 180, 181
Off-post	66	37306, 37307, 37308, 37309, 37310, 37312, 37313, 37320, 37323, 37327, 37330, 37331, 37332, 37333, 37334, 37335, 37336, 37337, 37338, 37339, 37340, 37341, 37342, 37343, 37344, 37345, 37346, 37347, 37348, 37349, 37350, 37351, 37352, 37353, 37354, 37355, 37356, 37357, 37358, 37359, 37360, 37361, 37362, 37363, 37364, 37366, 37367, 37368, 37369, 37370, 37371, 37373, 37374, 37377, 37378, 37381, 37382, 37383, 37385, 37386, 37389, 37391, 37392, 37395, 37396, 37397
Total Unconfined Wells = 737		

Table 3.1-1 (cont'd.)

Section No.	Total Wells	Wells
Confined Wells		
1	32	015, 016, 019, 022, 023, 025, 028, 029, 030, 031, 032, 034, 035, 036, 037, 039, 040, 042, 043, 045, 046, 048, 050, 071, 072, 522, 534, 537, 554, 568, 586, 588
2	35	004, 009, 010, 012, 013, 015, 016, 019, 021, 022, 024, 025, 027, 028, 030, 031, 032, 033, 035, 036, 038, 039, 041, 042, 043, 044, 045, 046, 047, 048, 545, 578, 580, 583, 585
3	5	003, 004, 006, 007, 012
4	3	009, 011, 012
5	3	001, 002, 003
6	2	004, 005
7	2	004, 005
8	2	004, 005
9	2	003, 004
11	2	003, 004
12	2	003, 004
19	10	002, 005, 006, 007, 011, 015, 016, 017, 018, 019
22	9	002, 023, 024, 027, 028, 030, 031, 079, 080
23	34	054, 055, 056, 061, 062, 125, 144, 161, 176, 177, 180, 181, 183, 184, 186, 187, 189, 190, 192, 193, 200, 201, 209, 218, 219, 222, 224, 225, 227, 228, 230, 234, 236, 340
24	21	080, 082, 083, 087, 089, 090, 109, 120, 125, 126, 136, 137, 159, 167, 168, 171, 172, 174, 175, 197, 198
25	25	004, 007, 008, 009, 010, 012, 013, 014, 016, 017, 019, 020, 021, 023, 024, 025, 026, 028, 029, 031, 033, 034, 037, 039, 040
26	59	022, 023, 024, 025, 026, 027, 028, 029, 029, 043, 047, 051, 052, 053, 054, 055, 056, 057, 058, 060, 061, 064, 066, 067, 069, 072, 074, 075, 077, 079, 080, 082, 084, 086, 089, 090, 092, 094, 096, 097, 123, 128, 129, 130, 134, 135, 136, 140, 141, 142, 144, 146, 147, 149, 150, 152, 153, 155, 156

Table 3.3-1 Chemicals Analyzed in FY88

Organochlorine Pesticide Compounds

Aldrin
Chlordane
Dieldrin
Endrin
Hexachlorocyclopentadiene
Isodrin
p,p'-DDE
p,p'-DDT

Organophosphorous Compounds

Atrazine*
Malathion*
Parathion*
Supona*
Vapona*

Volatile Organohalogen Compounds

1,1 Dichloroethylene
1,1 Dichloroethane
1,2 Dichloroethane
1,1,1 Trichloroethane
1,1,2 Trichloroethane
trans-1,2-Dichloroethylene
Carbon Tetrachloride
Chloroform
Methylene Chloride
Tetrachloroethylene
Trichloroethylene

Volatile Aromatic Compounds

Benzene
Chlorobenzene
Ethylbenzene
Toluene
Xylene (m)
Xylene (o,p)

Phosphonate Compounds

Diisopropylmethyl phosphonate (DIMP)
Dimethylmethyl phosphonate

DBCP

Dibromochloropropane

Metals

Arsenic
Cadmium
Chromium
Copper
Lead
Mercury
Zinc

Cations

Calcium
Magnesium
Potassium
Sodium

Anions

Alkalinity (as CaCO₃)
Chloride
Fluoride
Nitrate + Nitrite
Sulfate

Agent Products

Thiodiglycol*

*Analytes included in the winter 1987/88 sampling event only (Tasks 25 and 44 analytes).

Table 3.3-1 (cont'd.)

Organosulfur Compounds

1,4-Dithiane
1,4-Oxathiane
Benzothiazole
Dimethyldisulfide
p-Chlorophenylmethysulfide
p-Chlorophenylmethysulfone
p-Chlorophenylmethysulfoxide

DCPD/MIBK

Dicyclopentadiene
Methylisobutyl Ketone

Table 3.1-1 (cont'd.)

Section No.	Total Wells	Wells
Confined Wells (cont'd.)		
27	4	054, 055, 058, 060
28	5	025, 026, 028, 029, 030
29	2	002, 003
30	7	004, 005, 006, 007, 008, 010, 011
31	6	002, 006, 007, 008, 010, 011
32	2	002, 003
33	10	015, 016, 026, 027, 028, 029, 031, 032, 034, 035
34	8	003, 004, 006, 007, 010, 011, 012, 013
35	40	005, 008, 009, 012, 014, 015, 016, 017, 021, 024, 027, 028, 030, 032, 033, 036, 038, 039, 041, 050, 051, 054, 055, 056, 059, 060, 062, 063, 066, 067, 068, 070, 071, 073, 074, 080, 082, 083, 084, 089
36	36	009, 010, 024, 029, 036, 043, 047, 057, 061, 062, 066, 068, 072, 078, 079, 083, 086, 092, 099, 104, 105, 110, 113, 114, 116, 117, 118, 119, 121, 122, 138, 140, 147, 178, 179, 183
Off-post	14	37316, 37317, 37318, 37319, 37321, 37322, 37365, 37372, 37376, 37379, 37380, 37387, 37388, 37390
Total Confined Wells = 382		

Table 3.2-1

Wells Sampled During Winter 1987/88 Monitoring Program

Section No.	Total Wells	Wells Sampled
<u>Unconfined Wells¹</u>		
1	20	002, 004, 007, 008*, 010, 012, 013, 014*, 017, 018, 021, 027, 047, 510*, 511*, 516*, 517, 524, 525*, 539*
2	9	003, 005, 006, 007, 014, 020, 023, 034, 037
3	5	002*, 005*, 008, 518, 523*
4	13	007, 008, 010, 014, 021, 024, 027, 030, 038, 041, 042, 044, 045
6	2	002, 003
7	1	001
8	1	003
9	7	002*, 005, 006, 008, 010, 011, 013
11	1	002
12	1	002
19	2	001, 003
22	18	005, 006*, 008, 011, 015, 016, 017, 018, 019, 021*, 033, 043, 049, 051*, 053, 059, 062*, 065
23	46	004*, 007, 009, 011, 029*, 033, 043, 047, 048, 049, 050, 052, 053, 057, 058, 085, 095*, 096, 102, 106, 108, 118, 119, 120, 123, 140, 142, 150, 151, 178*, 179*, 182, 185*, 188*, 191*, 196, 197, 198, 202, 203, 204, 205, 208, 211, 231, 232
24	42	003, 008, 013, 024, 027, 049, 063, 081, 086, 092*, 094, 101, 106*, 107, 108, 111*, 112, 113*, 117, 124, 127*, 130, 135, 161, 162, 163, 164, 166, 178*, 179, 180, 181, 182, 183, 184, 185, 186, 187, 188, 199, 200, 201
25	4	011*, 015*, 018*, 038
26	15	006, 011, 015, 017, 019, 020, 041, 071, 073, 076, 083, 085, 088, 127, 133

* Indicates wells for which GC/MS analyses were conducted

¹ Corresponding Figure: 4.3-1

Table 3.2-1 (cont'd.)

Section No.	Total Wells	Wells Sampled
<u>Unconfined Wells (cont'd.)</u>		
27	27	001, 002, 003, 005, 016, 024, 026, 028, 031, 040, 049, 051, 053, 057, 063, 064, 068, 071, 072, 073, 074, 075, 076, 077, 078, 085, 086
28	3	022, 023, 027
30	1	009
31	1	005
33	9	001, 002, 003, 030, 033, 039, 063, 075, 077
34	7	002, 005, 008, 009*, 507, 508, 515
35	6	013, 023, 037, 052, 058, 065*
36	20	001*, 016, 019, 065, 069, 074, 075, 076*, 080, 081, 082*, 084*, 085, 090*, 100, 109, 112, 139*, 141, 142*
Off-post	67	37308, 37309*, 37312, 37313, 37320, 37323, 37327, 37330, 37331, 37332*, 37333*, 37334, 37335, 37336, 37337, 37338, 37339, 37340, 37341, 37342, 37343, 37344*, 37345, 37346, 37347, 37348, 37349, 37350, 37351, 37352, 37353, 37354, 37355, 37356, 37357, 37358, 37359*, 37360, 37361, 37362, 37363, 37364, 37366, 37367, 37368, 37369, 37370, 37371, 37373, 37374, 37377, 37378, 37381, 37382, 37383, 37385, 37386, 37389, 38391, 37392, 37395, 37396, 39397
Boller, CIII*, XII, XXIA		
Total Unconfined Wells = 328		
<u>Confined Wells²</u>		
1	6	015*, 022, 031*, 036, 048, 050
2	12	021, 025, 030, 031, 032, 033, 035, 038, 039, 043, 543, 573
3	3	003*, 004, 006
4	2	009*, 011

* Indicates wells for which GC/MS analyses were conducted

² Corresponding Figure: 4.3-2

Table 3.2-1 (cont'd.)

Section No.	Total Wells	Wells Sampled
<u>Confined Wells (cont'd.)</u>		
6	2	004, 005
7	1	004
8	1	005
9	1	003
11	1	004
12	2	003, 004
19	2	015, 017
22	6	023, 024*, 027*, 028, 030, 031
23	15	161, 177, 180, 181, 183, 184, 186, 187, 189*, 190, 192, 193*, 200, 201, 209
24	11	089, 109, 120*, 136, 137, 167, 168, 171, 172, 174, 175
25	9	009, 013*, 014, 016*, 017, 019*, 021, 023, 039
26	14	057, 058, 061, 066, 067, 072, 075, 084, 086, 089, 129, 140, 142, 147
27	2	054, 055
28	2	025, 026
30	1	011
32	1	002
33	4	016, 026, 032, 034
34	2	003, 006
35	11	012*, 016*, 017, 036, 038, 039, 054, 059*, 066*, 067, 068
36	13	066, 071, 072, 083, 104, 110*, 113*, 114, 117, 119, 140, 154, 592*

* Indicates wells for which GC/MS analyses were conducted.

Table 3.2-1 (cont'd.)

Section No.	Total Wells	Wells Sampled
<u>Confined Wells (cont'd.)</u>		
Off-post	14	37316, 37317, 37318, 37319, 37321, 37322, 37365, 37372, 37376, 37379, 37380, 37387, 37388, 37390
Total Confined Wells = 138		

* Indicates wells for which GC/MS analyses were conducted.

Table 3.2-2 Wells Sampled During Spring 1988 CMP Semiannual Monitoring Program

Section No.	Total Wells	Wells Sampled
<u>Unconfined Wells¹</u>		
1	2	069, 070
2	2	050, 052
3	4	002, 011, 517, 523
4	27	007, 010, 014, 016, 019, 020, 024, 026, 029, 030, 035, 036, 037, 038, 039, 040, 041, 042, 043, 044, 045, 046, 047, 048, 049, 050, 051
9	8	001, 002, 005, 008, 010, 013, 014, 015
22	4	008, 015, 021, 053
23	18	049, 095, 108, 142, 150, 151, 188, 198, 202, 204, 220, 221, 223, 226, 231, 232, 233, 235
24	13	013, 092, 106, 135, 161, 183, 185, 188, 191, 196, 199, 200, 201
25	8	022, 041, 042, 043, 044, 046, 047, 048
26	13	005, 015, 017, 020, 041, 063, 073, 083, 085, 088, 127, 133, 148
27	16	007, 016, 025, 028, 031, 042, 044, 053, 056, 057, 071, 072, 074, 084, 085, 086
28	4	018, 022, 023, 027
33	18	001, 025, 033, 048, 063, 064, 066, 068, 074, 075, 076, 077, 078, 079, 509, 514, 578, 581
35	9	018, 020, 061, 065, 077, 079, 081, 087, 088
36	10	094, 123, 137, 139, 146, 168, 169, 177, 180, 181
Off-post	62	37306, 37307, 37308, 37309, 37310, 37312, 37313, 37320, 37323, 37327, 37331, 37332, 37333, 37334, 37335, 37336, 37337, 37338, 37339, 37341, 37342, 37343, 37344, 37345, 37346, 37347, 37348, 37349, 37350, 37351, 37352, 37353, 37354, 37355, 37356, 37357, 37358, 37359, 37360, 37361, 37362, 37363, 37364, 37366, 37367, 37368, 37369, 37370, 37371, 37373, 37374, 37377, 37378, 37381, 37383, 37386, 37389, 37391, 37392, 37395, 37396, 39397
Total Unconfined Wells = 218		

¹ Corresponding Figure: 4.3-1

Table 3.2-2 (cont'd.)

Section No.	Total Wells	Wells Sampled
<u>Confined Wells²</u>		
1	2	071, 072
3	3	003, 004, 012
4	2	011, 012
22	6	023, 027, 028, 030, 079, 080
23	14	177, 181, 190, 192, 218, 219, 222, 224, 225, 227, 228, 230, 234, 236
24	4	136, 175, 197, 198
25	1	004
26	14	055, 067, 069, 084, 089, 090, 096, 146, 149, 150, 152, 153, 155, 156
27	2	055, 060
28	2	025, 028
33	4	026, 031, 032, 034
34	3	011, 012, 013
35	12	008, 016, 017, 021, 036, 062, 066, 080, 082, 083, 084, 089
36	7	114, 170, 171, 178, 179, 182, 183
Off-post	13	37316, 37317, 37318, 37321, 37322, 37365, 37372, 37376, 37379, 37380, 37387, 37388, 37390
<hr/>		
Total Confined Wells = 89		

² Corresponding Figure: 4.3-4

Table 3.2-3 Wells Sampled During Summer 1988 CMP Quarterly Monitoring Program

Section No.	Total Wells	Wells Sampled
<u>Unconfined Wells¹</u>		
23	12	049, 095, 108, 142, 179, 188, 191, 220, 221, 237, 239, 241
26	13	015, 017, 019, 020, 041, 071, 073, 083, 085, 127, 133, 148, 157
27	1	016
Total Unconfined Wells = 26		
<u>Confined Wells¹</u>		
23	5	181, 189, 190, 192, 222
26	15	066, 067, 072, 075, 084, 086, 129, 140, 142, 146, 149, 150, 153, 155, 156
Total Confined Wells = 20		

¹ Corresponding Figure: 4.3-5

Table 3.2-4 Comparison of Water Remedial Investigation and CMP Winter 1987/88 Well Networks for Selected Areas

	WRI Report* Wells (Spring 1987)	Winter 1987/88 Wells
Western Tier (Sections 3, 4, 9, 33)	76	44
Boundary Containment Systems (Sections 22, 23, 24)	141	139
North Plants Area (Section 25)	13	13
Basin F Area (Section 26)	28	29
Basin A Area (Section 36)	20	33
South Plants Area (Sections 1, 2)	38	47
Off-post Area	74	81

* April to July 1987, Third Quarter FY87.

Table 3.2-5

[illegible]

Table 3.2-6 FY88 Welis Sampled for Gas Chromatography and Mass Spectrometry Analysis

Well No.	Aquifer* Designation	Task 4		Task 44	TMP
		3rd Qtr	4th Qtr		
01008	U			x	
01012	U				
01014	U	x			x
01015	C				x
01020	U	x			
01021	U	x	x		
01023	C		x		
01031	C				x
01510	U				x
01511	U				x
01516	C				x
01525	U				x
01539	U				x
02019	C	x			
02020	U		x		
02030	C	x			
02034	U		x		
02035	C	x	x		
02037	U	x			
02038	C	x			
02039	C	x			
03002	U				x
03003	C				x
03005	U	x			x
03523	U	x			x
04007	U	x			
04009	C			x	
04014	U		x		
04021	U		x		
04027	U		x		
04030	U	x			
04033	U	x			
06005	C	x			
07001	U	x			
09002	U			x	

* U = Unconfined

C = Confined

** Only nontarget information available for these wells

*** Analysis not reported

Table 3.2-6 (cont'd.)

Well No.	Aquifer* Designation	Task 4		Task 44	TMP
		3rd Qtr	4th Qtr		
09005	U	x			
11002	U	x			
22006	U				x
22021	U	x			x
22024	C	x			x
22027	C				x
22051	U			x	
22059	U		x		
22060	U		x		
22062	U				x
23004	U			x	
23029	U			x	
23095	U		x		x***
23125	C		x		
23142	U	x			
23177	C	x			
23178	U				x
23179	U	x	x		x
23182	U		x		
23183	C		x		
23185	U	x		x	x
23188	U	x			x
23189	C			x	
23190	C	x			
23191**	U			x	
23192**	C		x		
23193	C			x	
24092	U			x	x
24106	U			x	
24111	U			x	
24113	U			x	x
24120	C			x	
24127	U			x	x
24150	U	x			
24178	U	x	x		x
24185	U		x		

* U = Unconfined

C = Confined

** Only nontarget information available for these wells

*** Analysis not reported

Table 3.2-6 (cont'd.)

Well No.	Aquifer* Designation	Task 4		Task 44	TMP
		3rd Qtr	4th Qtr		
25011	U				x
25013	C				x
25015	U				x
25016	C		x		x
25018	U				x
25019	C				x
25023	C	x			
26011	U		x		
26015	U		x		
26017	U		x		
26020	U		x		
26041	U	x	x		x
26066	C	x			
26071	U				x
26073	U	x			
26083	U	x			
26084	C	x			
26085	U	x			
26086	C	x			
26127	U	x	x		x
26128	C	x			
26133	U	x	x		x
26140	C	x			
26142	C		x		
27005	U				x***
27016	U		x		
27040	U	x			
27049	U			x	
27051	U				x
27053	U		x		
27055	C			x	
27062	U	x			
27074	U			x	
28023	U				x
28025	U	x			x
28027	U	x			

* U = Unconfined

C = Confined

** Only nontarget information available for these wells

*** Analysis not reported

Table 3.2-6 (cont'd.)

Well No.	Aquifer*	Task 4		Task 44	TMP
		3rd Qtr	4th Qtr		
32002	U				x
33002	U			x	
33024	U		x		
33026	U		x		
33030	U		x		x
33032	C				x
33034	C		x		
33060	U	x			
33063	U			x	
34005	U				x
34006	C				x
34008	U				x
34009	U				x
35012	C	x			x
35013	U	x			
35016	C			x	
35037	U		x		
35038	C		x		
35052	U	x			
35058	U		x		
35059	C				x
35063	C		x		
35065	U	x	x		x
35066	C			x	
36001	U	x			x
36065	U		x		
36076	U	x			x
36082	U	x	x		x
36084	U			x	
36090	U			x	x
36110	C			x	x
36112	U	x			x
36113	C				x
36121	C		x		
36139	U			x	x

* U = Unconfined

C = Confined

** Only nontarget information available for these wells

*** Analysis not reported

Table 3.2-6 (cont'd.)

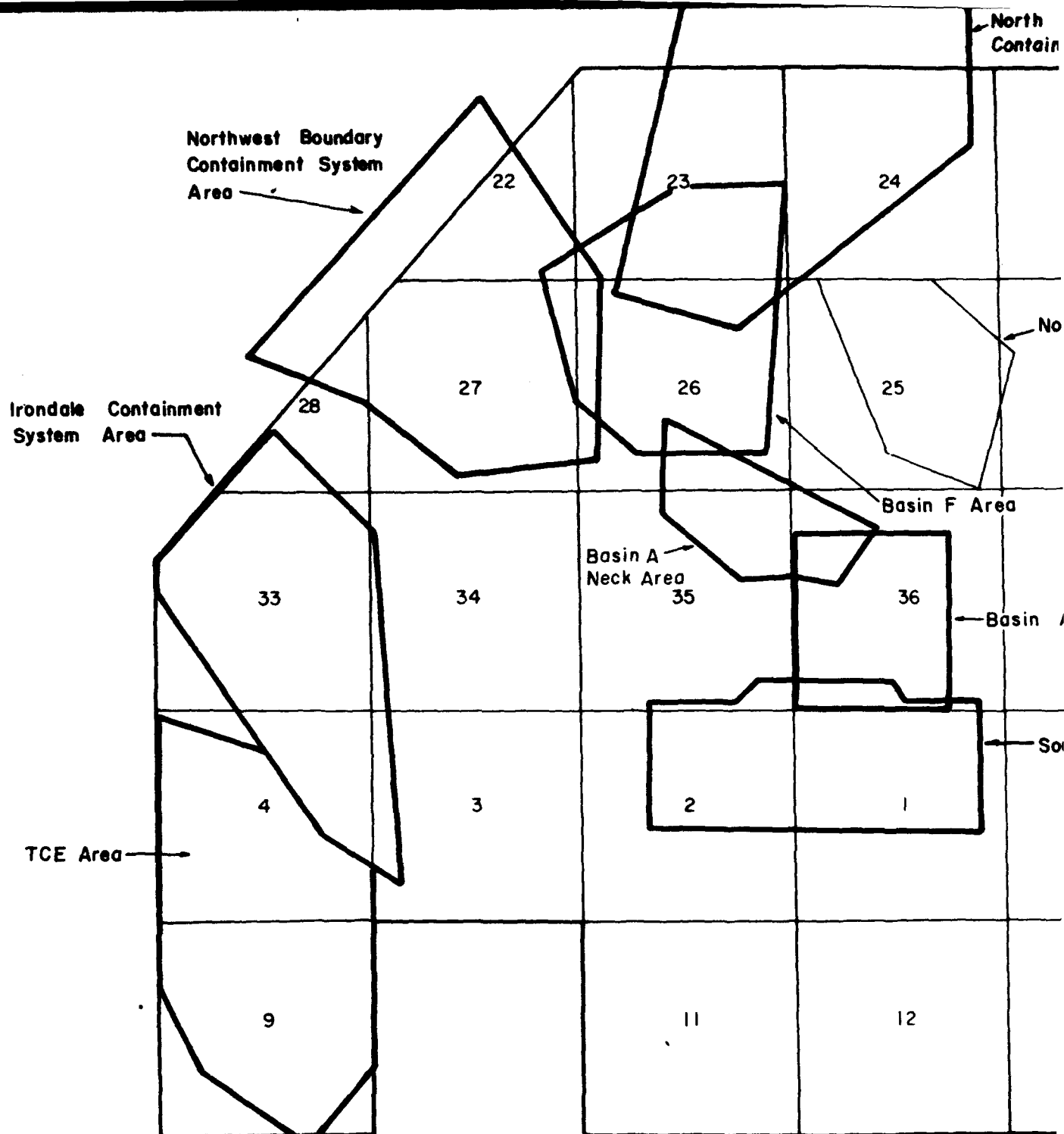
Well No.	Aquifer* Designation	Task 4		Task 44	TMP
		3rd Qtr	4th Qtr		
36142	U				x
36592	C				x
37305	U		x		
37307	U	x			
37308	U	x			
37309	U			x	
37312	U	x			
37313	U		x		
37320	U		x		
37332	U	x		x	
37333	U			x	
37343	U	x			
37344	U			x	
37347	U		x		
37349	U		x		
37353	U	x	x		
37354	U	x			
37356	U		x		
37357	U		x		
37359	U			x	
BOLLER	U	x			
CIII	U			x	

* U = Unconfined

C = Confined

** Only nontarget information available for these wells

*** Analysis not reported



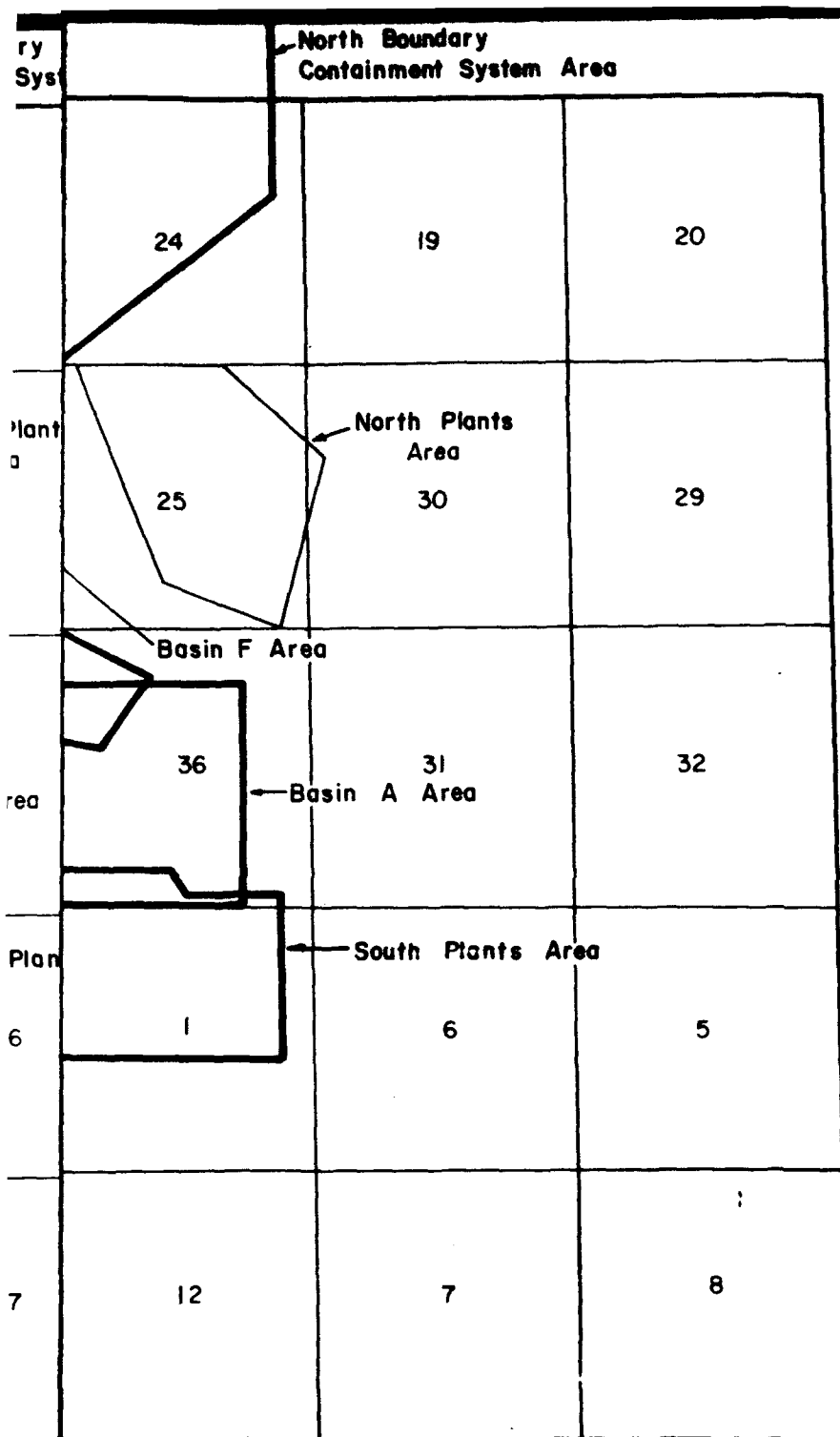
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Program

Rocky

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Drafted: 4/



Prepared for :

Program Manager's Office for
Rocky Mountain Arsenal
Commerce City, Colorado

Drafted : 4/29/88

FIGURE 3.2-1

**Designated Areas for the Comprehensive
Ground-Water Monitoring Program**

CMP Ground-Water Monitoring Annual Report
Prepared by : R.L. Stollar and Associates, Inc.

3.0 PROGRAM STRATEGY AND METHODOLOGY

The Comprehensive Monitoring Program at RMA consists of monitoring well networks, both on- and off-post, for monitoring water level fluctuations and water-quality changes. The water-level network has 1,119 wells that are monitored on a quarterly basis. The water-quality network has 467 wells that may be monitored annually, semiannually or quarterly. The monitoring frequency depends on the current level of understanding of contaminant distribution in the well area, remedial activities in its vicinity, and other factors that are discussed below.

The well network was designed to meet program objectives efficiently by using an optimal combination of monitoring wells, monitoring frequency and analytical suite. This section of the Annual Report discusses the strategy and criteria for the monitoring network design and the methodology for using water-quality and water-level monitoring networks. In addition, the CMP network is compared to previous monitoring networks. The water-level monitoring network is described in Section 3.1; the water-quality monitoring network is covered in Section 3.2; and the CMP analytical program is discussed in Section 3.3.

3.1 Water-level Monitoring Network

3.1.1 Well Selection Criteria for the Water-level Monitoring Network

The network of wells used to monitor potentiometric surfaces at RMA was selected after reviewing well construction data and historical water-level data. The areal distribution of wells was also evaluated. The quality and reliability of data from each well were assessed by comparison with data from nearby wells. Water-level data from the spring 1987 monitoring period (Tasks 25 and 44) were used as the primary basis for selecting wells for the CMP water-level network because these data represented the most recent comprehensive set of measurements throughout RMA.

However, if a well was located in a critical area, it was retained in the water-level network even if its construction was not considered adequate for water-quality sampling. A low construction ranking is tolerated for water-level data if the construction problem does not impact the representativeness of the measurements. For example, if an unconfined well is not properly sealed, it will still provide adequate water-table measurements.

Wells within the water-level monitoring network are monitored on a quarterly basis. The current network consists of 1,119 wells. This includes 737 unconfined wells and 382 confined wells (Table 3.1-1).

3.1.2 Well Selection Criteria for the Unconfined Flow System

The general philosophy for selecting wells in the unconfined flow system was to retain all wells that had been measured previously unless a specific situation warranted deleting a well from the program. Because of the important vertical hydraulic data provided by well clusters representing water levels at several depth intervals, no cluster of this kind was deleted from the program. Therefore the CMP water-level network includes all wells measured during Task 44, with the exception of the following:

1. Wells that were dry during spring 1987; these wells were generally used to indicate the areal extent of unsaturated alluvium;
2. Wells with construction data that indicate they are unacceptable for water-level monitoring;
3. Wells located within 500 ft of other wells that provide similar data; and
4. Wells that had poor quality Task 44 data.

3.1.3 Well Selection Criteria for the Confined Flow System

The majority of confined flow system wells was included in the water-level monitoring network because ground-water flow patterns in the confined flow system are less understood than are flow patterns in the unconfined flow system. Until flow patterns in the confined flow system are better understood, the data do not generally warrant deleting any wells. However, there were isolated conditions under which confined flow system wells were deleted from the program. These conditions included dry wells and wells that historically provided poor quality water-level measurements and which were located near other confined flow system wells. In total, less than 15 wells were deleted from the confined flow system water-level network.

3.2 Water-quality Monitoring Networks

The on-post water-quality monitoring network was designed to address two objectives. The first objective was to confirm presently understood contaminant distributions in general areas and to record possible distribution changes. The second objective was to provide detailed descriptions of

contaminant distribution in specific areas of concern. The specific areas monitored are shown in Figure 3.2-1. General areas are all areas outside of designated specific area boundaries.

General areas are those where less detailed description of water quality is required, and therefore the wells that are monitored in general areas are spaced less densely. Additionally, general area wells are only sampled on an annual basis. The general areas include known contamination locations as well as areas where contamination has not yet been detected. Where contamination is already present, contaminant distributions have been sufficiently defined with spatial and temporal data to justify a less densely-spaced network. Where no contaminants have been detected, wells are monitored to ascertain whether or not contamination is moving into these areas.

Specific areas are those for which additional data, more frequent data collection, and denser well spacing are needed to improve our understanding of site conditions. Water-quality monitoring is conducted in these areas on a semiannual basis. One of the two semiannual monitoring rounds is conducted at the same time as the annual well monitoring in the general areas. Specific areas have also been designated where additional and more frequent data are needed to support ongoing projects. In these cases, these wells are sampled quarterly. Two of the quarterly monitoring rounds are conducted in conjunction with CMP annual and/or semiannual monitoring.

The Transitional Monitoring Program (TMP) was the first annual sampling round conducted under the CMP. The Transitional Monitoring Program was prepared as soon as practical following contract award to ensure temporal continuity between previous Remedial Investigation ground-water investigations (Tasks 25 and 44) and the CMP. Because the TMP well network was designed as a transition plan and was sampled before the CMP Ground-water Technical Plan was completed (Stollar, 1988), it is not consistent in several respects to that plan. The temporal relationship of the TMP to the other sampling programs is described below and is illustrated in Figure 3.2-2. The former Task 44 well network was used as the basis for developing the transitional ground-water well network. This original well network was modified at working sessions that included all CMP Memorandum of Agreement parties. The result was the TMP network, which was perceived and used both as the interim link and as the initial CMP monitoring round.

3.2.1 FY88 Water-quality Monitoring

CMP water-quality monitoring was done during FY88 with three monitoring networks: annual, semiannual and quarterly. The annual FY88 sampling round is referred to as the winter 1987/88 event. In addition to the TMP, this round included two other sampling programs, Tasks 25 and 44. Of these, the largest well network was the TMP, which although it was similar to, was not the

same as the annual network described in the CMP Technical Plan. The wells sampled during the winter 1987/88 event were: 255 wells from TMP, 145 wells from Task 25, and 67 off-post wells from Task 44 (Table 3.2-1). Tasks 25 and 44 were included in the winter 1987/88 event to help assess regional ground-water quality conditions. The Boundary Systems Monitoring Program (Task 25) was conducted at the same time as the TMP, and the data from several wells were used for both programs. Those wells designated for both TMP and Task 25 rounds were monitored as part of the Task 25 program. At the time the TMP was implemented, all the off-post wells had recently been sampled under the Task 44 regional monitoring program. To avoid duplicated effort, no off-post wells were sampled as part of the TMP.

The first semiannual sampling round was in the spring of 1988. It was designed to provide more focused data in 9 specific on-post areas and throughout the off-post area in order to maintain or improve the understanding of site conditions in those areas. All previously monitored off-post wells were included in the semiannual network to allow continued assessment of off-post contaminant distribution.

The smallest monitoring network was used for quarterly sampling. This network was designed to provide data to support ongoing projects in specific areas.

The data from the three sampling programs were obtained over a six month time frame. As a result, error may have been introduced because of variations in water quality over time. However, the magnitude of these variations, considering the short time lapse and the large investigative area, is expected to be small.

The wells proposed for sampling differed from the wells actually sampled in the three monitoring networks of the winter 1987/88 sampling event. The TMP well network originally consisted of 294 wells. Seventeen wells were included in both the TMP and the Task 25 network and were sampled as part of Task 25. Of the 277 remaining TMP wells, 22 were either dry or were destroyed. A total of 255 wells was therefore sampled as part of the TMP.

The CMP Technical Plan proposed sampling 375 wells in the semiannual event. The well network for spring 1988 consisted of 307 wells (Table 3.2-2). However, 31 proposed wells in Sections 1 and 2 were not sampled because of concurrent water-quality monitoring in this area by Morrison-Knudsen/Shell Chemical Company (Shell). Data from spring 1988 Morrison Knudsen/Shell sampling effort were not available at the time this report was prepared.

The quarterly monitoring network was sampled from June to July (summer 1988). Although 51 wells had been proposed for this round, only 46 were sampled (Table 3.2-3). Of the 5 wells not sampled, 3 unconfined wells (23238, 26065 and 26145) were dry, and 2 confined flow system wells (23180 and 23193) were bailed dry and well recharge was insufficient for sampling.

3.2.1.1 Comparison with Previous RMA Networks. The Task 44 well network evolved from several previous RMA monitoring networks, including the Task 4 Initial Screening Program and Final Screening Program (Quarters 3 and 4), the Off-post Contamination Assessment, and the new monitoring well installed as part of the Composite Well Program. The Task 44 sampling program was the Water Remedial Investigation, and the Task 44 analytical results for spring 1987 are presented in the WRI Report (Ebasco, 1989). In the Water Remedial Investigation Program, 474 wells were sampled, 74 of which were located off-post. The winter 1987/88 monitoring network consisted of 468 wells. Table 3.2-4 is a comparison of Water Remedial Investigation (spring 1987) and CMP winter 1987/88 well network sizes for selected RMA areas.

The biggest difference in the number of wells monitored in the spring 1987 and winter 1987/88 sampling networks was in the Western Tier. Although 76 wells were sampled in the Western Tier during the spring 1987 event, only 44 wells were sampled in that area during the winter 1987/88 event. Even when a similar number of wells was sampled in a given area for the two rounds, some of the specific wells sampled may have been different.

3.2.2 FY88 Water-quality Data Presentation and Use

Analytical data collected as part of the CMP during FY88 are discussed in Section 4.0 and are presented graphically in both Section 4.0 and Appendix A. Regional contaminant distributions, based on FY88 results, are presented for 18 analytes and analyte groups in Table 3.2-5. In contrast, semiannual and quarterly results are presented for a reduced list of 6 analytes and analyte groups, which are discussed below. These 6 analytes were selected for more detailed discussion because they were most representative of the contaminant distribution in the specific areas monitored during the CMP.

The CMP Technical Plan outlines an approach for designing the on-post monitoring network that consisted of sampling in general and specific areas. The contaminant data for the specific areas (sampled on a semiannual basis) was assessed to learn which contaminants were most representative of the nature and extent of contamination in these areas. Six analytes and analyte groups were identified from this review. They are: DIMP, DBCP, volatile aromatic organics (VOAs), volatile

organohalogens (VOHs), Dieldrin and fluoride. The specific areas are listed below, with the representative analytes identified for each area:

1. North Boundary Containment System Area - DIMP, VOAs, VOHs and fluoride are the major contaminants of concern in this area. DIMP has been detected off-post and an associated plume extends 10 mi north of RMA (Geraghty & Miller, 1986).
2. Northwest Boundary Containment System Area - VOAs, VOHs and fluoride are the principal contaminants in the vicinity of the Northwest Boundary Containment System, which was designed to intercept the DBCP plume in this area.
3. Irondale Containment System Area - DBCP is the main contaminant of concern in this area. Several spills of unknown volume in the Rail Classification Yard are the probable source of contaminants in this area.
4. Trichloroethylene (TRCLE) Area - VOHs and fluoride contamination are of principal concern in this area. There is a well documented TRCLE plume in this area that may be originating off-post (Ebasco, 1988).
5. Basin A Area - Dieldrin, DIMP, DBCP, VOHs and fluoride are the major contaminants of concern here. Dieldrin, DIMP and DBCP were disposed of in Basin A (Geraghty & Miller, 1986). The discharge of 400 tons of sodium fluoride (NaF) into Basin A from North Plants is also documented (Geraghty & Miller, 1986). The highest localized concentrations of VOHs, attributable to chloroform, are located in this area.
6. Basin A Neck Area - DIMP, DBCP, VOHs, Dieldrin and fluoride are the major contaminants within this area. The center of mass of the DIMP plume is in Basin A Neck (Geraghty & Miller 1986).
7. South Plants Area - DBCP and VOAs are the contaminants of concern in this area. There are records of several spills of DBCP and VOAs in South Plants and South Plants tank farm. The highest levels of VOA contamination on RMA are located in the South Plants area.

8. Basin F Area - Dieldrin, DIMP, VOHs, notably chloroform, and DBCP are the major contaminants of concern in this area.

9. North Plants Area - DIMP is the main contaminant of concern in this area. Portions of the DIMP plume appear to originate in North Plants.

Winter 1987/88 data were selected for presentation in this report because they are the most comprehensive and representative of regional water quality throughout RMA. In contrast, the spring 1988 semiannual round provided data to assess contaminant transport in the 9 specific areas (Figure 3.2-1). The summer 1988 round provided the data necessary to comply with substantive regulatory requirements for the Basin F area.

Both spatial and temporal variability in contaminant distributions were assessed to achieve the objectives of the CMP. Spatial variability of contaminants due to variations in hydrogeologic conditions were described and the observed extent of contaminant transport was compared to migration distance calculated on the basis of available hydrogeologic and hydrochemical information. Temporal variations in regional water quality were assessed for FY88 by comparing winter 1987/88 analytical results with those presented in the Water Remedial Investigation Report (spring 1987). Temporal variations in water quality in specific areas were evaluated by comparing data from the annual (winter 1987/88) and semiannual (spring 1988) rounds of the CMP for each of the designated 6 key analytes or analyte groups.

3.2.3 Well Selection Gas Chromatography/Mass Spectrometry Analysis

Gas chromatography and mass spectroscopy (GC/MS) analysis was planned for approximately 20 percent of the samples collected from either the annual or the semiannual sampling rounds. A total of 59 wells were selected for analysis by GC/MS during FY88 (Table 3.2-6). The purpose of these analyses was to provide confirmation of target analytes that were detected by gas chromatography (GC). In addition, the GC/MS analysis was conducted to identify tentatively non-target compounds. Wells were selected on the basis of:

- historical chemical data,
- use of wells for previous GC/MS analyses, and
- well construction data.

Although 59 wells were selected for GC/MS analysis, only 58 were used. Two wells (23095 and 27005) were not sampled, and one well (32002) was added to the program. Historical chemical

data were used to assess wells where a range of concentrations of multiple target analytes were present. Those wells were preferred for GC/MS analyses because they provided diverse results for comparison. Wells that had been used for previous GC/MS analysis were used where possible to provide continuity with previous GC/MS programs. Of the 59 wells selected for the CMP GC/MS program, 25 had been evaluated by GC/MS analysis during Tasks 4 and 44. Well construction data was another factor in selection. Well construction was evaluated from the point of view of both the reliability of the data from the well and the ability to associate the well with a specific geologic zone.

3.2.4 CMP Procedures for Water-quality Monitoring

Several documents in addition to the CMP Ground-water Technical Plan give detailed information on different methods and procedures used to monitor water quality. For example, ground-water sampling procedures are discussed in the CMP "Field Procedures Manual," laboratory procedures are covered in the CMP "Analytical Methods Manual," and the CMP "Quality Assurance/Quality Control Plan" discusses sample handling and chain-of-custody. The general "Data Management Plan" addresses data management procedures applicable to all phases of the CMP. The "Health and Safety Plan" for the CMP describes how to conduct CMP ground-water monitoring safely to prevent chemical exposures and personal injuries.

3.3 Analytical Program

The ground-water samples collected during the CMP sampling rounds were tested for the analytes listed in Table 3.3-1. These analytes are mostly the same analytes specified under Task 44 of the Remedial Investigation/Feasibility Study. However, the spring and summer 1988 sampling events did not include organophosphorus pesticide analytes (atrazine, malathion, parathion, supona and vapona), nor thiodiglycol, which had been analyzed for under Task 44. Datachem, Inc. and Enseco-Cal Laboratories analyzed all the FY88 water-quality samples.

The CMP Technical Plan (Stollar, 1988) proposes that parathion, cyanide and acid extractables be included in the CMP list of analytes. These analytes have been included in the FY89 CMP analytical suite.

The CMP analytical program included analysis of approximately 20 percent of all ground-water samples by the GC/MS analytical technique. GC/MS analyses confirmed target analytes detected by gas chromatography. Additionally, GC/MS analysis was used to detect nontarget analytes. The CMP is consistent with prior RMA practice in that an effort is made to evaluate nontarget

compounds and to decide (if they are detected repeatedly at elevated levels) whether to add them to the target analyte list. The results of the GC/MS analyses are discussed in Section 4.4 of this report.

The CMP analytical program also incorporated a quality assurance and quality control plan designed to ensure accurate and reproducible analytical results. The CMP quality assurance and quality control plan discusses quality assurance review processes and specifics such as *monitoring* analytical controls, control samples, and sample lot controls. The results of the quality assurance and quality control program are discussed in Section 4.5 of this report.

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4.0 RESULTS OF FY88 PROGRAM

Results of three sampling rounds during FY88 are discussed in Section 4.0: winter 1987/88, spring 1988 and summer 1988. A comparison of the water table maps generated from well water measurements in the unconfined flow system are presented and discussed in Section 4.1. Winter 1987/88 potentiometric surface maps of the confined flow system are presented in Section 4.2. Water level data are contained in Appendix B. Section 4.3 is a presentation of the contaminant distribution for 18 analytes and/or analyte groups. The lateral and vertical distribution of each of these analytes within the unconfined and confined flow systems is discussed in Sections 4.3.2 through 4.3.15. Plume maps for those analytes present in the unconfined flow system are included within the text, and point plots for the confined flow system are contained in Appendix A. Gas chromatography/mass spectrometry (GC/MS) results used for data confirmation and tentative identification of unknown compounds are discussed in Section 4.4. The results of the CMP quality assurance and quality control program are presented in Section 4.5. The analytical results from the three FY88 sampling events are presented in Appendix C on a diskette.

4.1 Water Table in the Unconfined Flow System

Water-table maps for RMA were developed from water-level data obtained from wells in the unconfined flow system. The maps correspond to the winter 1987/88 event, the spring 1988 event and the summer 1988 event. These maps are contoured on 10-ft intervals (Plates 4.1-1 through 4.1-3). More detailed water-table maps using 2-ft contour intervals were prepared for the boundary systems area (Figures 4.1-1 through 4.1-3).

The general configuration of each of the water-table maps is similar and shows that unconfined ground water generally flows toward the north and northwest RMA boundaries. Local variations in flow patterns, such as the north, northeast flow component that occurs between Basin F and the North Boundary Containment System, are not reflected on Plates 4.1-1 through 4.1-3 because they reflect a larger contour interval. The water-table maps were compared with the Time-averaged Water Table Map presented in the Water Remedial Investigation Draft Final Report (WRI Report), (Ebasco, 1989) to identify areas of fluctuating water levels and changing hydraulic gradients.

In areas of unsaturated alluvium, data from wells completed in shallow strata of the unconfined flow system were checked to verify that the water level was within the unconfined flow system. Data that did not meet this criterion were not used to map the water table. The water-level contours in areas of unsaturated alluvium represent the approximate position of the water table in

the unconfined flow system. Areas of unsaturated alluvium are not differentiated from areas of saturated alluvium on the water table maps.

4.1.1 Winter 1987/88 Water-Table Map

Hydraulic gradients estimated from the winter 1987/88 water-table maps (Plate 4.1-1) (all plates inserted in back) (Figure 4.1-1) range from 0.002 in Sections 23 and 24 to 0.080 northwest of the Northwest Boundary Containment System. For purposes of comparison, hydraulic gradients were calculated for the same locations as listed in the Water Remedial Investigation Report, Appendix F Section 2.4, and were found to be similar.

The steepest hydraulic gradients were observed in the Basin A Neck, the northwest region of Basin F, northwest of the North Boundary Containment System, and north of the Northwest Boundary Containment System. The flattest gradients were in the central portions of Sections 23 and 24 and in the eastern part of RMA.

The 5,140 ft contour line in Sections 23 and 24 appears to reflect the effects of the North Boundary Containment System. This is shown by the near east-west trend of the 5,140 ft contour line, in contrast to the southwest-northeast trend of other contour lines.

Changes in hydraulic gradient magnitudes and directions between the western and central portions of the study area are attributed to the contrast between more permeable gravels in the West and less permeable eolian deposits and bedrock in the central area. The hydraulic gradients and flow directions shown on the winter 1987/88 water-table map are consistent with general hydrologic trends observed in previous monitoring programs.

4.1.2 Spring 1988 Water-table Map

Generally, the spring 1988 and winter 1987/88 water-table maps are similar (Plate 4.1-2 and Figure 4.1-2). The hydraulic gradient northwest of the Northwest Boundary Containment System is steeper on the spring 1988 water-table map (Figure 4.1-2). However, this feature is consistent with the Third Quarter FY87 water-table contour map and the time-averaged water-table contour map presented in the Water Remedial Investigation Report (Ebasco, 1989). The operation of the Northwest Boundary Containment System and the proximity of unsaturated alluvium are reflected in the steep hydraulic gradient and variations in ground-water flow direction in this area. The area south of the North Boundary Containment System has the same general configuration as shown on the winter 1987/88 map and the time-averaged map of the Water Remedial Investigation Report.

4.1.3 Summer 1988 Water-table Map

The general trends noted in the winter 1987/88 and spring 1988 water-table contour maps are also evident on the summer 1988 water-table maps (Plate 4.1-3 and Figure 4.1-3). Steeper hydraulic gradients exist northwest of the North Boundary Containment System and northeast of the Northwest Boundary Containment System. The water table in the central areas of Sections 23 and 24 has a flatter hydraulic gradient, with both north and northeast directions of flow.

In the northeast quadrant of Section 35, the magnitude and direction of hydraulic gradient is different from those indicated on the winter 1987/88 and spring 1988 water-table maps. Differences are due to the addition of Well 35020 to the network in summer 1988. There are no comparative historical water-level measurements for this well. Continued monitoring of Well 35020 will allow reassessment of the seasonal fluctuations in water level in this well.

In the area of Basin F, the height of the water table increased from winter and spring 1988 to summer 1988. This increase resulted in a steeper gradient toward the Northwest from Basin F.

4.2 Potentiometric Surface Maps of the Confined Flow System

This section presents a discussion of the potentiometric surface maps constructed for zones A, 1U, 1, 2, 3 and 4 of the unconfined flow system. These maps are based on water-level data obtained from wells completed within each zone. A description of the lithologic characteristics and stratigraphic relationships are contained in Sections 2.1.2 and 2.2.2.

Potentiometric surfaces did not vary significantly during the first year of CMP monitoring. This was expected because head in the confined flow system is less subject to changes associated with seasonal weather patterns than in the unconfined flow system. Water-level fluctuations in zones at boundary containment systems were neither expected nor observed during FY88. Because of the lack of temporal fluctuations in potentiometric data during FY88, only one monitoring period is illustrated (winter 1987/88).

Water-level measurements from more than 360 wells were used to generate potentiometric surface maps for zones A through 4 from the winter 1987/88 monitoring event. Monitoring well locations for each zone were compared to the Denver Formation subcrop map (Ebasco, 1989, Plate 11) to verify that the zone associated with each well was identified correctly. As shown by the well locations in each zone on Figures 4.2-1 through 4.2-6, wells that monitor upper portions of the

stratigraphic section are found more to the Southeast, in a band trending southwest-northeast, parallel to the strike of the Denver Formation. This relationship is the result of RMA contamination patterns. Because the unconfined flow system is widely impacted and monitored, whatever zone lies below this system is more closely monitored. Therefore, most wells are completed in zones near subcrop areas.

Discussions of potentiometric surfaces are presented for each zone in order of stratigraphic succession, from the oldest unit to the youngest unit. Potentiometric surface maps were not generated for zones B, VC, 5, 6, 7, 8 and 9 because data were sparse from these zones throughout the RMA study area.

Zone 4 was the deepest zone for which sufficient data were available to construct potentiometric surface maps (Figure 4.2-1). Water levels were measured in 33 wells screened in zone 4 during winter 1987/88. The potentiometric surface indicates that the predominant flow direction is northward in areas east of "D" Street at the North Boundary Containment System and in areas west of Section 27. Flow is to the West-northwest in Sections 3, 22, 27 and 34. Flow is north and northwest in Sections 14, 23 and 26. Hydraulic gradients in zone 4 range from 0.004 in Sections 24 and 25 to 0.015 in Section 27.

For the winter 1987/88 event, 24 wells screened in zone 3 provided water-level data used to construct the potentiometric surface map. Figure 4.2-2 indicates that ground water flows almost due west in Sections 22, 26 and 27 near the northwest boundary of RMA. Flow is more northerly in Sections 23 and 24, while a northwesterly flow direction is seen in sections along the RMA western tier. Hydraulic gradients within zone 3 range from 0.024 to 0.005. The steeper hydraulic gradients are located in Sections 22 and 27, whereas the flatter gradients correspond to the central areas of Sections 23 and 24 south of the North Boundary Containment System.

Potentiometric data obtained from approximately 60 wells were used to construct Figure 4.2-3, which illustrates the configuration of the potentiometric surface of zone 2 for winter 1987/88. Figure 4.2-3 indicates ground-water flow is to the North in the southern portions of off-post Sections 13 and 14. The hydraulic gradient measures 0.008 for these sections, but is only 0.004 in the central portions of Sections 23 and 24. More permeable lithologic material may be the cause of flatter hydraulic gradients in central Sections 23 and 24. Data from Sections 3, 27 and 34 show ground water to be flowing westerly, with an approximate hydraulic gradient of 0.028. Variations in ground-water flow directions in Section 26 may be the result of highly variable lithology encountered in the zone 2 interval.

Potentiometric data from 57 wells screened in sandstone intervals within zone 1 were used to construct the potentiometric surface map for winter 1987/88 (Figure 4.2-4). The general trend of ground-water flow is north-northwest over most of the northern areas of RMA. Ground water in Sections 25, 26 and 36 flows in a northerly direction. Zone 1 hydraulic gradients throughout most of RMA range from 0.004 along the central and northern sections to 0.010 along the Basin A Neck Pathway from central Section 36, and northwest to the zone 1 subcrop boundary in southeastern Section 27. Steeper gradients in the northeast area of Basin A (Section 36) are probably indicative of low-permeability claystones and volcanoclastic materials associated with zone 1 sandstones in that area.

A monitoring network of 37 wells screened in zone 1U provided data used to construct the potentiometric surface map for winter 1987/88 (Figure 4.2-5). Within the southwestern and south-central portions of Section 2, ground-water flow is influenced by contrasting permeabilities along an axis trending northwest-southeast. Low hydraulic gradients in portions of Section 2 and in western portions of Section 1 reflect the higher permeability of channel sandstones in this area. The hydraulic gradient ranges from 0.006 to 0.013. Steep hydraulic gradients in central and southeastern Section 26 and northern Section 35 (0.010 to 0.013) were found to be consistent with previous observations in the Water Remedial Investigation Report (Ebasco, 1989). Extreme gradients and variations in ground-water flow directions may be due to hydrologic connection of zone 1U to upper units.

The potentiometric surface map of zone A for winter 1987/88 was constructed from water levels measured in 48 wells (Figure 4.2-6). The variability in apparent ground-water flow directions may be the result of preferential flow in channel sandstones in this zone.

The highest hydraulic gradients in zone A are in the south-central part of Section 35 and the north-central area of Section 2. They range from 0.020 to 0.080. Hydraulic gradients in the central and eastern sections range from 0.009 to 0.004. The areas of lower hydraulic gradients and northerly flow direction corresponds with areas of increased permeability.

4.3 Contaminant Distribution

Assessment of ground-water quality within the RMA study area is based on: (1) chemical analysis of samples collected during winter 1987/88, spring 1988 and summer 1988; (2) current understanding of stratigraphic correlations of various geologic units or zones at RMA; and (3) current understanding of ground-water flow conditions at RMA. Consistent with the objectives of the CMP, the spatial variability of contaminants was assessed within a single monitoring period,

while temporal variability was evaluated through comparison of CMP data with historical contaminant distribution information. Historical data were derived primarily from the Water Remedial Investigation Report, but data from as far back as the Initial Screening Program were also reviewed.

Ground-water samples were collected in sampling rounds under various monitoring programs, including the TMP, CMP and Tasks 25 and 44. In this report, the winter 1987/88 monitoring period includes Task 25 and TMP sampling conducted at that time, as well as the last sampling event of Task 44 (off-post wells only) that preceded these two sampling efforts and was concluded in October 1987. CMP sampling during FY88 also included water-quality monitoring during spring and summer 1988.

Ground-water samples collected during FY88 were analyzed for a suite of parameters defined by the needs of each program or task. The target analyte suite presented in Table 3.3-1 is a comprehensive list of target analytes for the winter 1987/88, spring and summer 1988 monitoring rounds. The analytical suites specific to each task or program are identified in their respective technical plans.

Quantitative analyses of the ground-water samples collected during the winter 1987/88 and CMP sampling rounds were performed by one of four laboratories in accordance with USATHAMA- and EPA-approved methodologies. Samples collected during Tasks 25 and 44 were submitted to ESE laboratories. Samples collected during the Transitional Monitoring Program and CMP sampling rounds were submitted for analyses either to Datachem, Inc. or to Enseco-Cal Laboratories. Analytical data from each monitoring task may be found in Appendix C.

Analytical results obtained during the past year of CMP work are presented in the sections that follow. Data from several tasks or programs were considered for presentation in this annual report. The strategy used to integrate these data is discussed in Section 4.3.1.1 below. The means of data presentation and graphics preparation are described in Section 4.3.1.2.

4.3.1 Strategy and Methods for Analytical Data Presentation

The CMP Technical Plan (RLSA, 1988) identified three tiers of monitoring networks and frequencies for collection of analytical data. The analytical data presented here conform to the Technical Plan guidelines for only two of the three periods covered. This is because of the timing of initial CMP monitoring and the completion of the Technical Plan. In general, the monitoring period designated as winter 1987/88 is analogous to the annual network described in the Technical

Plan, but is not identical to it. This period represents monitoring performed from September 1987 to February 1988 for the transition period from Task 44 to CMP monitoring. The well network for winter 1987/88 will be discussed in Section 4.3.1.1 below. The spring 1988 and summer 1988 periods represent the CMP semiannual and quarterly monitoring, respectively.

Graphical depictions of analytical results were prepared for selected monitoring tasks. The graphical presentations in this section were prepared to illustrate contaminant areal distribution for a given time period. To assess temporal variability in contaminant distribution, the data from the winter 1987/88 period were compared to recent historical data presented in the Water Remedial Investigation Report and in the Initial Screening Program Task 4 Report (ESE, 1987). Methods used to graphically illustrate data in this chapter are described more fully in Section 4.3.1.2.

In this report, comparisons of current FY88 data were made to Initial Screening Program historical data (winter 1985/86) to assess temporal changes in contaminant distributions that may indicate contaminant migration. In addition to possible temporal changes in contaminant distribution, differences between these data sets may result from monitoring well network changes, changes in contour values used, and laboratory analytical variability. Because hydrologic and geologic characteristics were not considered in the Initial Screening Program graphic presentations, the maps should not be interpreted as "plume" maps. Nonetheless, because the Initial Screening Program data are the oldest set of information that has sampling and quality analysis and quality control standards similar to those for CMP data, its results were used for comparison to the CMP.

Because of the multiple sources of data variability, assessments of variations in plume configurations attributed to post-Initial Screening Program contaminant migration should be viewed as preliminary. The contaminant distributions in the unconfined flow system are better understood than those in the confined flow system. Therefore comparisons were made between the initial Screening Program and the CMP for the unconfined flow system only.

4.3.1.1 Strategy Used to Integrate Analytical Results from Multiple RMA Monitoring Programs.

Analytical results presented in this section were derived primarily from the winter 1987/88 monitoring event. Several sampling efforts are collectively referred to in this report (Figure 4.3-1) as the winter 1987/88 event. These include Task 44 off-post sampling (September to October 1987), Task 25 sampling (October 1987 to February 1988) and TMP sampling (October 1987 to February 1988).

The results of the three sampling efforts were combined for presentation as the winter 1987/88 sampling event. This was done primarily to provide a comprehensive network of wells that could

be viewed in a regional context and to provide greater well density in specific areas of concern. The elapsed time for the winter 1987/88 sampling event was six months. Program-specific differences for the three events, such as laboratories with varying Certified Reporting Limits (CRLs), are discussed according to specific analytes later in Section 4.3. The winter 1987/88 sampling networks for the unconfined and confined Denver Formation ground-water flow systems are presented in Figures 4.3-1 and 4.3-2.

4.3.1.2 Data Presentation. Ground-water samples were collected during the spring 1988 field effort for CMP semiannual monitoring. CMP semiannual monitoring includes both on-post and off-post wells in specific areas of concern, as defined in the CMP Technical Plan. Ground-water samples were collected from May to June 1988. The spring 1988 sampling networks for the unconfined and confined flow systems are presented in Figures 4.3-3 and 4.3-4.

Ground-water samples were collected during summer 1988 for CMP quarterly specific-area monitoring. CMP quarterly specific-area monitoring in summer 1988 included only on-post Basin F area wells, with ground-water samples being collected from July to August 1988. The summer 1988 sampling networks for the unconfined and confined flow systems are both presented in Figure 4.3-5.

Compound distributions for selected analytes listed in Table 3.3-1 were generated for the winter 1987/88, spring 1988 and summer 1988 sampling networks. Contaminant plume maps in the unconfined flow system were produced for those compounds or compound groups identified as most representative of RMA contamination (Ebasco, 1989). Confined flow system contaminant point plots are also provided for compounds that best illustrate contamination in confined flow system zones.

The regional distribution of contaminants represented by the winter 1987/88 period is illustrated graphically for 18 compounds, compound groups and inorganic chemicals. Table 3.2-5 lists the plume maps for the unconfined flow system and the confined flow system point plots for the winter 1987/88 and spring 1988 sampling rounds presented in this annual report.

Where composite maps of compound groups are presented, individual compounds within a compound group are similar in chemical structure, physical properties or origin. Compounds presented in composite group plume maps or point plots are dithiane and oxathiane, the organosulfur compounds, 4-chlorophenylmethyl sulfide, sulfoxide and sulfone, the VOAs, and the VOHs. Composite concentrations were calculated by summing concentrations above certified

reporting limits for individual compounds at each well. Summed concentrations were used to produce the composite maps.

The results of the CMP semiannual (spring 1988) and quarterly (summer 1988) sampling events are discussed in this report in the context of 6 key analytes or composite analyte groups. These compound groups are considered most representative of the contaminant distribution trends in the specific areas monitored during the CMP semiannual and quarterly monitoring. These compounds include: DIMP, DBCP, Dieldrin, VOAs, VOH and fluoride. The VOA and VOH groups comprise 5 and 11 analytes. The CMP distribution of selected analytes is graphically presented and compared with other CMP sampling rounds as well as with Water Remedial Investigation Report results. Semiannual analytical results are graphically presented and discussed for these key compounds in an effort to better assess contaminant migration in specific areas of concern. FY88 quarterly data are presented for each of these key analytes in Section 4.3's contaminant distribution discussions.

Plume maps of contaminant distribution presented in this section were prepared using:

1. Current analytical data;
2. Geologic data to identify zones or units where continuous ground-water flow and contaminant migration are expected to occur;
3. Hydrogeologic data to identify variations in hydraulic conductivity; and
4. Potentiometric data to evaluate ground-water flow direction and hydraulic gradients.

Contaminant distribution in the unconfined flow system is represented by contour maps, whereas contaminant distribution in the confined flow system is shown as uncontroled point plots of analytical data. This was because of sparse areal detections of contaminants in the confined flow system.

Criteria for contouring plume maps were based on the CRL and the maximum contaminant concentrations detected. Contour intervals were selected to illustrate the contaminant concentration range throughout the CMP regional study area. Specific criteria used to contour plume maps are given below.

For all chemicals that do not occur naturally in the environment, contour plots were drawn using the CRL as the lowest contour value. For a compound where various CRLs occurred (as one result of using different laboratories), the highest CRL value was used as the lowest contour value on a plume map compound. Isolated detections located outside of plume contours were identified by concentration value. Plume maps for composite groups (i.e., VOAs and VOHs) were prepared using the highest CRL for any particular analyte within that composite group as the lowermost contour value on the plume map.

The contaminant distribution discussions that follow have been prepared to describe spatial variations in contaminants, both regionally and in specific areas of concern. Assessments of these data and discussions of the temporal variations in ground-water flow patterns and contaminant flow are provided in Section 5.0.

4.3.2 Dieldrin

Analyses for Dieldrin were performed on 460 ground-water samples collected during the winter 1987/88 monitoring program. Dieldrin concentrations ranging from 0.051 to 150 $\mu\text{g/l}$ were detected in 155 of the 460 samples. Dieldrin concentrations above the CRL were detected in samples within zones VC, A, IU and 1-5 of the confined flow system. The distribution of Dieldrin in the unconfined ground-water flow system is illustrated on the plume map in Figure 4.3-6 and is discussed in the following subsections. Dieldrin detections above the CRL in both the unconfined and confined flow systems are summarized in Table 4.3-1 for the 1988 program.

4.3.2.1 Unconfined Flow System. Dieldrin concentrations above CRLs were detected in 136 of 325 ground-water samples. Concentrations ranged from 0.052 to 150 $\mu\text{g/l}$. The CRLs for the various monitoring programs were 0.050 $\mu\text{g/l}$ for the Transitional Monitoring Program, 0.054 $\mu\text{g/l}$ for Task 25, and 0.054 and 0.060 $\mu\text{g/l}$ for Task 44. The highest CRL for the three quarters (0.060 $\mu\text{g/l}$) was used as the lowest contour value in constructing the contaminant distribution map shown in Figure 4.3-6.

Six Dieldrin plumes were identified on-post. The contaminant migration pathways in which these plumes occur are illustrated in Figure 2.2-1. These pathways include:

- South Lakes Pathway;
- South Plants/Basin A Pathway;
- Central South Pathway;
- Central North Pathway;

- Basin F West Pathway; and
- Basin F Pathway.

The South Lakes Pathway plume extends west approximately 8,000 ft from the center of the South Plants area. Dieldrin concentrations within the plume ranged from 0.140 to 5.30 $\mu\text{g/l}$. The highest Dieldrin concentrations (5.30 $\mu\text{g/l}$) were in Well 02037, located approximately 500 ft north of Ladora Lake. Historically, this well had not shown Dieldrin detections. Therefore, the results from 02037 must be confirmed in subsequent sampling and analysis to gain credence.

The South Plants-Basin A Pathway plume extends north from the South Plants area beneath Basin A and northwest through the Basin A Neck Pathway. Dieldrin concentrations within the plume range from 0.100 to 8.00 $\mu\text{g/l}$. Well 01517 (8.00 $\mu\text{g/l}$), located immediately south of South Plants, has no historical data on which to base comparisons. The area within the plume where the highest concentrations were detected coincides with the ground-water mound beneath the South Plants area. The plume migrates radially away from this high, with primary flow apparent to the North and the West.

The Central South Pathway plume extends from the west central portion of Section 35 into the southwest corner of Section 27 in a northwesterly trend. Dieldrin concentrations within the plume ranged from 0.540 to 2.30 $\mu\text{g/l}$. Higher Dieldrin concentrations were detected in the western portion of the plume versus the southeast portion.

The Central North Pathway plume extends northwest from Section 35 through Section 27, where it merges with the Basin F West Pathway plume. Reported Dieldrin concentrations within the plume ranged from 0.090 to 4.90 $\mu\text{g/l}$.

The Basin F West Pathway plume extends northwest from the northwest corner of Section 26 to the Northwest Boundary Containment System. Reported Dieldrin concentrations within the plume ranged from 0.090 to 1.50 $\mu\text{g/l}$, with the highest concentrations detected south of the Northwest Boundary Containment System in Section 27. The Basin F Pathway plume extends along a north-northeastern trend from Basin F to the North Boundary Containment System. Dieldrin concentrations above the CRL within the plume ranged from 0.063 to 150 $\mu\text{g/l}$.

Four additional plumes that extend off-post to the North and Northwest of RMA have been identified, as shown in Figure 4.3-6. There are two northwest trending plumes near the Northwest Boundary Containment System. The southern plume is an extension of the Central North Pathway plume that continues north approximately 1,200 ft off-post. The more northern plume (directly

northwest of the Northwest Boundary Containment System) is approximately 4,500 ft in length. Dieldrin concentrations above the CRL for these two plumes ranged from 0.170 $\mu\text{g/l}$ in the southern plume to 0.590 $\mu\text{g/l}$ in the Northern Pathway plume. Additionally, two north trending plumes have been identified downgradient of the North Boundary Containment System. The more western plume extends along the First Creek Off-post Pathway north of the North Boundary Containment System for approximately 1,500 ft. Dieldrin concentrations ranging from 0.240 to 0.780 $\mu\text{g/l}$ were detected in this plume. The more eastern plume extends along the Northern Off-post Pathway north of the North Boundary Containment System for approximately 6000 ft. This plume contained Dieldrin concentrations above the CRL ranging from 0.080 to 0.140 $\mu\text{g/l}$.

4.3.3.1.1 Winter 1987/88 and Water Remedial Investigation Report Comparison. - Dieldrin distributions in the unconfined flow system were compared for the Water Remedial Investigation Report and the winter 1987/88 sampling programs by using the plume maps in Figure 4.3-6 of this report and in Figure 4.2-2 (Appendix F) of the Water Remedial Investigation Report. Dieldrin concentrations above the CRL were detected in 115 of 297 Water Remedial Investigation Report samples analyzed and in 136 of 325 winter 1987/88 samples. Similar Dieldrin plumes were reported for both sampling periods. These plumes and the Dieldrin concentrations detected during the two sampling periods are summarized as follows:

Plume	Concentration Ranges ($\mu\text{g/l}$)
South Lakes Pathway	
Water Remedial Investigation Report	0.080 - 2.94
Winter 1987/88	0.140 - 5.30
South Plants - Basin A Pathway	
Water Remedial Investigation Report	0.104 - 2.34
Winter 1987/88	0.100 - 8.00
Central South Pathway	
Water Remedial Investigation Report	0.088 - 1.22
Winter 1987/88	0.540 - 2.30
Central North Pathway	
Water Remedial Investigation Report	0.115 - 1.76
Winter 1987/88	0.090 - 4.90
Basin F West Pathway	
Water Remedial Investigation Report	0.103 - 1.35
Winter 1987/88	0.090 - 1.50
Basin F Pathway	
Water Remedial Investigation Report	0.090 - >2.06
Winter 1987/88	0.060 - 150

For Well 23053, in which the highest Dieldrin concentration ($150 \mu\text{g/l}$) was detected during the winter 1987/88 sampling period, a concentration of $>2.06 \mu\text{g/l}$ was reported in the Water Remedial Investigation Report. This difference in reported concentrations can be attributed to laboratory methods, as suggested by the ">" value. For Well 19003, in which the highest Dieldrin concentration ($8.92 \mu\text{g/l}$) was detected during the Water Remedial Investigation sampling period, a Dieldrin concentration of $5.30 \mu\text{g/l}$ was reported during the winter 1987/88 sampling period.

In general, concentrations reported during the winter 1987/88 sampling period were higher than those detected during the Water Remedial Investigation sampling period, but the differences (with the exception of the change noted in Well 23053) are within the likely range of variation for analytical methods. Thus, the data suggest no major changes in the plumes between the Water Remedial Investigation and the winter 1987/88 sampling periods.

The contaminant distribution shown by the winter 1987/88 plume map is generally similar to that depicted in the Water Remedial Investigation Report. There are, however, some variations worth noting.

1. The contaminant plume in the Central South Pathway appears larger in winter 1987/88. The winter 1987/88 map includes a northerly trend of the plume which, if it continues, will intersect the plume in the Central North Pathway.
2. The peak concentration shown in the Basin F Pathway during winter 1987/88 was not shown in the Water Remedial Investigation Report because of differences in maximum reported values.

4.3.2.1.2 Winter 1987/88 and Initial Screening Program Comparison. - To assess changes in the rate and extent of Dieldrin migration, comparisons are made between the winter 1985/86 Initial Screening Program Task 4 Dieldrin analytical results (ISP Report, Figure C-Z) and the CMP winter 1987/88 Dieldrin plumes shown in Figure 4.3-6.

Dieldrin is one of the few contaminants on RMA with a plume configuration indicating westward migration from the South Plants source area. This was also true in the Initial Screening Program. However, in the Initial Screening Program a Dieldrin detection in easternmost Section 3 was interpreted as isolated. In the CMP interpretation, well 03005 (Figure 4.3-6) is contoured as continuous with western South Plants Dieldrin detections.

Downgradient of the South Plants in the Basin A - Basin A Neck Area, Initial Screening Program and CMP reported results are very similar. West of this area in Sections 35 and 34, isolated Dieldrin detections in the Initial Screening Program are interpreted in the present CMP report as a continuous plume, possibly originating from the Sand Creek Lateral. In the Initial Screening Program, this northeast-trending alignment of isolated detections did not extend northward into Section 27, but CMP results indicate such an extension. The Dieldrin plume in Sections 35, 34 and 27 in Figure 4.3-6 is interpreted as nearly 8,000 ft long. It was presented in the Initial Screening Program as a mile-long alignment of three isolated detections.

In the Initial Screening Program, the plume that begins in the northwesternmost portion of Section 35 (Figure 4.3-6) was not contoured to the northwest; rather, it was contoured as continuous with Dieldrin contamination in Section 26. Widespread Dieldrin contamination in central Section 27 is presented both in the Initial Screening Program and in Figure 4.3-6. Dieldrin that migrates off-post, bypassing the Northwest Boundary Containment System, as shown in Figure 4.3-6, is not indicated by the Initial Screening Program results, and this may indicate significant plume migration as Initial Screening Program well control appears adequate in this area. However, analytical variability may account for the differences observed in this area because detections are slightly above the CRL.

Initial Screening Program and CMP results present the nature and extent of Dieldrin contamination in the Basin F - North Boundary Containment System area, but there are some exceptions. The Task 25 well network within the winter 1987/88 program gives much more data resolution to the CMP results than those results presented in the Initial Screening Program. High Dieldrin concentrations in Well 23053 and surrounding wells were not sampled in the Initial Screening Program, so some high concentrations were not presented. Concentrations in this area necessitated 5, 50 and 100 $\mu\text{g/l}$ isoconcentration contours on Figure 4.3-1, whereas the highest Initial Screening Program concentrations were enclosed within a 1 $\mu\text{g/l}$ isoconcentration contour.

4.3.2.1.3 Winter 1987/88 and Spring and Summer 1988 Comparison. - Samples from 44 of 216 wells sampled during the spring 1988 sampling period contained Dieldrin concentrations above the CRL ranging from 0.056 to 3.60 $\mu\text{g/l}$. Concentrations of Dieldrin above the CRL were detected in 23 of 26 ground-water samples collected during the summer 1988 sampling period. The concentrations ranged from 0.053 to 5.30 $\mu\text{g/l}$.

The distribution of Dieldrin detected during the spring 1988 sampling period is represented in Figure 4.3-7. The shapes of the Dieldrin plumes resemble each other in areas where the well networks were similar in the winter 1987/88 and spring 1988 events. However, there are some variations in concentrations between the plumes as listed below:

1. During the spring 1988 event, in the Central North Pathway plume the highest Dieldrin concentration was 0.636 $\mu\text{g/l}$, whereas 4.90 $\mu\text{g/l}$ had been reported for winter 1987/88. Well 27074, which had the reported maximum during winter 1987/88, was sampled during spring 1988 but only had a reported value of 0.122 $\mu\text{g/l}$.
2. The Basin F Pathway plume had a reported maximum of 150 $\mu\text{g/l}$ in well 23053 during winter 1987/88, but this well was not sampled during spring 1988. The maximum reported concentration during spring 1988 was 2.10 $\mu\text{g/l}$.
3. The First Creek Off-post Pathway plume did not extend as far during winter 1987/88 as it did in spring 1988. Wells 37312 and 37373 had reported concentrations of 1.20 and 1.00 $\mu\text{g/l}$, respectively, during spring 1988, but in winter 1987/88 were 0.140 $\mu\text{g/l}$ and below CRL.

A summary of Dieldrin concentrations for the quarterly specific-area monitoring is presented in Table 4.3-2.

4.3.2.2 Confined Flow System. Analyses for Dieldrin were performed on 135 ground-water samples collected from the confined flow system during the winter 1987/88 sampling round. Dieldrin concentrations above the CRL ranging from 0.051 to 0.844 $\mu\text{g/l}$ were detected in 19 of 135 samples analyzed. Dieldrin was reported above the CRL for the winter sampling program in all confined flow system zones except B, 6 and 7. Analytical results for the confined flow system samples from the winter 1987/88, spring 1988, and summer 1988 events are summarized in Table 4.3-1. Selected concentration plots from these sampling events are presented in Figures A-1 through A-8 for comparison with similar concentration plots that were included in the Water Remedial Investigation Report. The deepest Dieldrin contamination (0.069 $\mu\text{g/l}$) was in Well 03004, completed in zone 4 at a monitored depth of 177 ft below ground level. The lowest stratigraphic zone in which Dieldrin contamination was detected was zone 5 in Well 23184 (0.077 $\mu\text{g/l}$). This well's monitored depth was 120 ft.

The distribution of Dieldrin in the confined flow system rarely shows a clear relationship with the distribution of Dieldrin in the unconfined flow system. One exception to this is in the South Lakes Pathway, where a Dieldrin concentration of 0.844 $\mu\text{g/l}$ was reported. The well for which this was reported is in the same cluster as Well 19003, which had the areal concentration high of Dieldrin (5.30 $\mu\text{g/l}$) in the unconfined flow system.

4.3.2.2.1 Winter 1987/88 and Water Remedial Investigation Report Comparison. - Dieldrin concentrations above the CRL were detected in 10 of 140 ground-water samples analyzed during the Water Remedial Investigation, with concentrations ranging from >0.050 to 1.23 $\mu\text{g/l}$. Water Remedial Investigation analytical results, like those for the winter 1987/88 period, indicated Dieldrin concentrations above the CRL in zones A, 1, 2 and 3. In contrast, no Dieldrin was detected in zone VC in the Water Remedial Investigation, but it was reported in the winter 1987/88 period. A summary of these analytical results is presented in Table 4.3-1. Zone 3 was reported in the Water Remedial Investigation to have the highest Dieldrin concentration (1.23 $\mu\text{g/l}$ detected in Well 26142). During the winter 1987/88 sampling, the concentration of Dieldrin was 0.571 $\mu\text{g/m}^3$. The highest concentration reported for the winter 1987/88 sampling period (0.844 $\mu\text{g/l}$) was detected in Well 02038. During the Water Remedial Investigation sampling period, a concentration of 0.149 $\mu\text{g/l}$ was reported for this well. Sampling and/or analytical variability may account for the reported difference.

4.3.2.2.2 Winter 1987/88 and Spring and Summer 1988 Comparison. - During spring 1988, of 88 samples, 6 had Dieldrin concentrations ranging from 0.057 to 1.60 $\mu\text{g/l}$. The detections were located in zones A, 1U, 2 and 7. The deepest Dieldrin detection during spring 1988 was at 101 ft below ground level in Well 36183 (0.070 $\mu\text{g/l}$), completed in zone A. The lowest stratigraphic unit containing Dieldrin (0.354 $\mu\text{g/l}$) was in zone 7, Well 33026. The results from the wells sampled during winter 1987/88 and spring 1988 are comparable, with the exception of Well 26084. During winter 1987/88, Well 26084 had a reported Dieldrin concentration of 0.057 $\mu\text{g/l}$, whereas the reported concentration during spring 1988 was 0.432 $\mu\text{g/l}$.

Five of 20 samples had Dieldrin concentrations ranging from 0.046 to 0.577 $\mu\text{g/l}$ during summer 1988. The detections were located in zones 1, 2 and 3.

4.3.3 Endrin

Analyses were performed for Endrin on 460 ground-water samples collected during the winter 1987/88 program. The CRLs for the various monitoring programs were 0.050 $\mu\text{g/l}$ for the Transitional Monitoring Program, 0.060 $\mu\text{g/l}$ for Task 25, and 0.052 and 0.060 $\mu\text{g/l}$ for Task 44. Endrin concentrations above the CRL ranging from 0.057 to 63.0 $\mu\text{g/l}$ were detected in 81 samples. Endrin was detected above CRLs in 75 samples from the unconfined flow system, and in 6 samples from zones A, 1U, 2, 3 and 4 of the confined flow system. The distribution of Endrin in the unconfined flow system is illustrated in Figure 4.3-8. Endrin detections in both the unconfined and confined flow systems for the 1988 monitoring program are summarized in Table 4.3-3.

4.3.3.1 Unconfined Flow System. Endrin concentrations above the CRL were detected in 75 of 325 ground-water samples collected from the unconfined flow system during the winter 1987/88 monitoring program. Detected concentrations ranged from 0.057 to 63.0 $\mu\text{g/l}$. Endrin plumes were present in the South Plants area, south (upgradient) of the Northwest Boundary Containment System, downgradient of the Northwest Boundary Containment System, along the Basin F Pathway and along the First Creek Off-post Pathway (Figure 4.3-8).

The South Plants-Basin A plume encompasses portions of northwest Section 1 and southwest Section 36. The highest concentration detected within the plume was 6.00 $\mu\text{g/l}$ in Well 36001.

Endrin was detected south of the Northwest Boundary Containment System in a northwest trending plume that encompasses much of Section 27 and a portion of Section 22. Concentrations within this plume ranged from 0.050 to 0.530 $\mu\text{g/l}$. The contamination in this area is the result of

migration along the Basin A Neck Pathway, the Central North Pathway and the Basin F West Pathway. However, a clear relationship between the plume and Basins A or F is not evident.

The most extensive area of Endrin contamination is located along the Basin F Pathway. The highest concentration detected within the plume was 63.0 $\mu\text{g/l}$ in Well 23053, which is located approximately 4000 ft northeast of Basin F. Endrin was detected north of the North Boundary Containment System in a small plume along the First Creek Off-post Pathway.

4.3.3.1.1 Winter 1987/88 and Water Remedial Investigation Report Comparison. - Endrin distributions in the unconfined flow system for the Water Remedial Investigation and the winter 1987/88 sampling events were compared using the plume maps shown in Figure 4.3-8 and in Water Remedial Investigation Report Figure 4.2-4. Endrin distributions were similar for both sampling programs, except that Endrin was not detected in the South Plants area during the Water Remedial Investigation. These plumes and the Endrin concentrations detected during the two sampling periods are summarized as follows:

Plume	Concentration Ranges ($\mu\text{g/l}$)
South Plants Pathway	
Water Remedial Investigation Report	(No Detections)
Winter 1987/88	0.070 - 6.00
Central Pathway	
Water Remedial Investigation Report	0.154 - 0.329
Winter 1987/88	0.060 - 0.530
Basin F Pathway	
Water Remedial Investigation Report	0.076 - 1.51
Winter 1987/88	0.060 - 63.0

The South Plants-Basin A plume was defined by 5 Endrin detections above the CRL during the winter 1987/88 event. Endrin was not detected in this area in the Water Remedial Investigation. However, historical data reviewed during preparation of the Water Remedial Investigation Report indicated Endrin contamination in the area; Endrin was therefore shown on the Water Remedial Investigation Report plume map. Based on the data collected from 5 wells that were added to the winter 1987/88 sampling program, the plume was interpreted to include part of South Plants. During the winter 1987/88 program Endrin was detected at a concentration of 6.00 $\mu\text{g/l}$ in Well 36001, which has historically shown elevated Endrin detections, but concentrations below the CRL were reported for this well in the Water Remedial Investigation Report.

Endrin contamination in the Central Pathway was more widespread in the winter 1987/88 sampling program than in the Water Remedial Investigation. This may be attributed to the fact that 15 wells with detections reported above the CRL during the winter 1987/88 program yielded samples with Endrin concentrations below the CRL ($<0.060 \mu\text{g/l}$) during the Water Remedial Investigation. Fourteen of the 15 wells had prior detections below the CRL, and the fifteenth had detections above the CRL. The analytical results indicate an Endrin migration towards the Northwest Boundary Containment System, but whether the detections demonstrate actual plume migration or sampling and analytical variability cannot be assessed adequately at this time.

Distributions of Endrin along the Basin F Pathway were similar for both sampling periods; however, concentrations were generally higher for the winter 1987/88 program. Of the 36 Endrin detections above the CRL in this plume during the winter 1987/88 program, 23 were higher than those reported in the Water Remedial Investigation Report. The largest discrepancy occurred in analytical results for Well 23053, for which the highest Endrin concentration of $63.0 \mu\text{g/l}$ was reported during the winter 1987/88 program, compared to a concentration of $1.22 \mu\text{g/l}$ reported in the Water Remedial Investigation Report.

4.3.3.1.2 Winter 1987/88 and Initial Screening Program Comparison. - A comparison of the winter 1985/86 Initial Screening Program results (ISP Report, Figure C-3) for Endrin to the CMP results presented in Figure 4.3-8 is made here to assess changes in the rate and extent of Endrin migration.

Endrin concentrations detected in the South Plants are similarly contoured in both the Initial Screening Program and the CMP. Endrin contamination is localized at the extreme northwest corner of Section 1 and the southwest corner of Section 36 in both the Initial Screening Program and the CMP results.

Despite what appears to be adequate Initial Screening Program well control west of Basin F, widespread low-level Endrin contamination is upgradient of the Northwest Boundary Containment System as presented in Figure 4.3-8. This is absent from the Initial Screening Program results and may be a result of analytical variability.

In the Basin F-North Boundary Containment System area of RMA there are considerable differences in the Initial Screening Program and CMP data presentations. The Initial Screening Program results clearly indicate that Endrin contamination is immediately adjacent to and downgradient of Basin F. Endrin was also detected in the Basin C area. The Initial Screening Program results appear credible, as they are sufficiently above the CRL (some of the values are

within a 1 $\mu\text{g/l}$ isoconcentration contour). Endrin concentrations contoured in Figure 4.3-8 of this report are not immediately adjacent to Basin F, but are nearly 1,000 ft downgradient. There is one isolated Endrin detection in the Basin C area in this report. A noteworthy point is that most of the wells in the Basin F area are common to both the Initial Screening Program and CMP monitoring well networks, thus monitoring network variability does not contribute to the above assessment.

The Task 25 well network adds considerable resolution to the winter 1987/88 results. This complicates comparisons to the Initial Screening Program. In the Initial Screening Program, Endrin contamination in the Basin F area extended into the southern quarter of Section 23. In the CMP, the lateral extent of Endrin contamination was shown to be continuous downgradient to the North Boundary Containment System. CMP Endrin plume continuity is well established by numerous wells not sampled in the Initial Screening Program effort.

4.3.3.2 Confined Flow System. Endrin concentrations above the CRL ranging from 0.066 $\mu\text{g/l}$ to 0.080 $\mu\text{g/l}$ were detected in six of 135 samples analyzed from confined flow system zones A, 1U, 2, 3 and 4 during the winter 1987/88 monitoring program. Endrin concentrations in the confined flow system were highest and most frequent within the South Plants - Basin A area and the Basin A Neck area. Analytical results for the winter 1987/88 event are summarized in Table 4.3-3. Point plots of the confined flow system from the winter 1987/88 analytical results are presented in Figures A-9 through A-11.

The deepest Endrin contamination at RMA in winter 1987/88 occurred in Well 03004 at a depth of 177 ft below ground level and at a concentration of 0.070 $\mu\text{g/l}$. The deepest stratigraphic zone shown to be contaminated was zone 4 and this corresponded to this same well.

The distribution of Endrin contamination in the confined flow system does not show a clear relationship with Endrin in the unconfined flow system.

4.3.3.2.1 Winter 1987/88 and Water Remedial Investigation Report Comparison. - Water Remedial Investigation Report results indicate that Endrin concentrations above the CRL were detected in 4 of 140 samples analyzed during the Water Remedial Investigation, with concentrations ranging from >0.057 to 0.162 $\mu\text{g/l}$. Table 4.3-3 summarizes these results for each of the confined flow system zones. Of the 8 Endrin detections above the CRL in the winter 1987/88 event, 6 were reported as below the CRL in the Water Remedial Investigation Report. The other 2 detections were from wells not sampled during the Water Remedial Investigation. Similarly, 2 of the 4 detections above the CRL reported in the Water Remedial Investigation Report were below the

CRL during the winter 1987/88 event; the remaining 2 detections were from wells not analyzed during the winter 1987/88 program. Factors affecting changes in concentrations are not readily apparent, but may result from analytical method variability.

4.3.4 Dithiane and Oxathiane

Dithiane and oxathiane analyses were performed on 424 ground-water samples collected during the winter 1987/88 event. The dithiane and oxathiane CRLs were 1.34 and 2.38 $\mu\text{g/l}$ for the TMP, 3.34 and 1.35 $\mu\text{g/l}$ for Task 25, and 1.10 to 3.34 $\mu\text{g/l}$ and 1.35 to 2.00 $\mu\text{g/l}$ for Task 44. Detections of dithiane and oxathiane are presented here by summing the concentration of each and presenting the composite data. Composite detections ranged from 1.90 to 4320 $\mu\text{g/l}$ in 73 of the samples analyzed. Dithiane/oxathiane was detected above CRLs in confined flow system zones A, 1U, 1, 2 and 5. Dithiane/oxathiane analytical results for the 1988 monitoring program are summarized in Table 4.3-4.

4.3.4.1 Unconfined Flow System. During the winter 1987/88 monitoring program, 290 ground-water samples from the unconfined flow system were analyzed for dithiane/oxathiane. In 63 samples, dithiane/oxathiane concentrations ranged from 1.90 to 4320 $\mu\text{g/l}$. The highest CRL for the three quarters analyzed (3.34 $\mu\text{g/l}$) was used in constructing the contaminant plume map shown in Figure 4.3-9.

A continuous dithiane/oxathiane plume is interpreted to extend from northwest Section 1 via the South Plants-Basin A, Basin A Neck, and Basin F Pathways to the North Boundary Containment System. The continuity of the plume from the Basin A area to Basin F was largely interpreted from historical data. Winter 1987/88 analytical data do not firmly resolve dithiane/oxathiane configurations in the Basin A Neck Pathway. Downgradient of the North Boundary Containment System, a plume of dithiane/oxathiane occurs along the First Creek Off-post Pathway.

The furthest upgradient detection of dithiane/oxathiane occurred in the South Plants area. Based on the potentiometric surface of the unconfined flow system, it is likely that a ground-water mound beneath the South Plants area induces contaminant flow radially away from South Plants. Concentrations above CRLs in this plume ranged from 3.34 to 4320 $\mu\text{g/l}$, with the area of highest concentration reported in Section 36 beneath Basin A. To the North, the plume extends across Basin A and northwest into the Basin A Neck. Based on historical information, the plume is interpreted as continuing north from the Basin A Neck into Section 26 and the Basin F Pathway. Flow is predominantly through areas of saturated alluvium, except in portions of Section 1 and

through Section 26, where flow occurs in the unconfined Denver Formation beneath areas of unsaturated alluvium.

The First Creek Off-post plume extends northwest from the North Boundary Containment System approximately 4,000 ft through Section 14. Concentrations ranged from 5.93 to 15.4 $\mu\text{g/l}$. Flow is predominantly through areas of saturated alluvium.

4.3.4.1.1 Winter 1987/88 and Water Remedial Investigation Report Comparison. - Dithiane/oxathiane distributions in the unconfined flow system for the Water Remedial Investigation and winter 1987/88 programs were compared using the plume maps shown in Figure 4.3-9 of this report and in Figure 4.2-5 (Appendix F) of the Water Remedial Investigation Report. In the Water Remedial Investigation, dithiane CRLs were 1.10, 1.59 and 3.34 $\mu\text{g/l}$, whereas oxathiane CRLs were 1.35 and 2.00 $\mu\text{g/l}$. Water Remedial Investigation Report dithiane/oxathiane concentrations above CRLs were detected in 58 of 267 samples analyzed; in winter 1987/88 CRLs, concentrations above CRLs were found in 63 of 290 samples analyzed.

High concentrations of dithiane/oxathiane were reported for both sampling periods in the South Plants-Basin A Pathway, Basin A Neck Pathway, Basin F Pathway, and the First Creek Off-post Pathway. Concentrations ranged from 1.25 to 9310 $\mu\text{g/l}$ for the Water Remedial Investigation Report and from 1.35 to 4320 $\mu\text{g/l}$ for the winter 1987/88 monitoring program. The highest concentrations reported from both sampling periods were located in the South Plants-Basin A Pathway, and in Basin A Neck Pathway in Section 36. The wells with reported concentration highs were not common to either sampling event.

The areal distribution of dithiane/oxathiane appears generally similar between the Water Remedial Investigation and the winter 1987/88 period. One notable difference is that the winter 1987/88 network data indicate that dithiane/oxathiane contamination includes the South Plants area. This is a result of wells being added in the South Plants area in winter 1987/88. In addition, the width of the plume shown for winter 1987/88 in the First Creek Off-post Pathway is wider than shown in the Water Remedial Investigation. The increased width is a result of a difference in interpretation between the two events regarding the north side of the plume.

4.3.4.1.2 Winter 1987/88 and Initial Screening Program Comparison. - In an attempt to assess the changes in the rate and extent of dithiane/oxathiane migration, the winter 1987/88 CMP analytical results (Figure 4.3-9) were compared to the winter 1985/86 Task 4 Initial Screening Program results as presented in Figure 3.2-8 of that report.

The general configurations of dithiane/oxathiane distribution are very similar in both the CMP and Initial Screening Program interpretations. Plumes are interpreted to originate in the South Plants/Basin A area, migrate northward via Basin A Neck into the Basin F area, and continue northward to the North Boundary Containment System. In the CMP, the configuration described above is evident (Figure 4.3-9). In the Initial Screening Program, however, dithiane/oxathiane distribution is discontinuous at the Basin A Neck. Also, the Initial Screening Program results indicate (with good well control) that dithiane/oxathiane contamination did not extend as far north as the North Boundary Containment System. Conversely, CMP results indicate a plume existing both at and downgradient of the North Boundary Containment System.

In the Basin A-Basin A Neck area, CMP results exhibit considerably higher concentrations near the north end of Basin A. Initial Screening Program detections in the Basin A area are enclosed within a 50 $\mu\text{g/l}$ isoconcentration contour (the highest), whereas CMP isoconcentration contours in Figure 4.3-9 range from 50 to 1000 $\mu\text{g/l}$. Actual data values are very similar for both programs.

There is additional historical information presented in Spaine, et al. (1984) that indicates dithiane contamination was widespread at concentrations greater than 100 $\mu\text{g/l}$ in the Basin A-A Neck area. This information was also presented in Figure 3.2-12 of the Initial Screening Program; the isoconcentration contours indicate there were historic dithiane detections in Basin A greater than 3000 $\mu\text{g/l}$. The utility of comparisons involving the Spaine information is complicated by differences in sampling, quality assurance/quality control, and analytical procedures. Also, well control is not presented on the Spaine map, and this serves to further complicate variability assessments.

4.3.4.2 Confined Flow System. During the winter 1987/88 event, analyses for dithiane/oxathiane were performed on 134 ground-water samples collected from the confined flow system. Analytical results for the winter 1987/88 sampling program are summarized in Table 4.3-4. Confined system point plots from the winter 1987/88 analytical results are presented in Figures A-12 through A-15.

Dithiane/oxathiane concentrations above CRLs ranging from 1.34 to 341 $\mu\text{g/l}$ were detected in 10 of 134 samples analyzed from confined flow system zones A, 1U, 1, 2 and 5. Concentrations in the confined flow system were highest at the northern end of Basin A in Section 36. The deepest detection of dithiane/oxathiane (4.98 $\mu\text{g/l}$) was found at 157 ft below ground level in Well 04009, confined in zone 5.

The areal distribution of confined and unconfined flow systems contamination by dithiane/oxathiane is interpreted to indicate downward contaminant migration. This is shown by the highest concentrations in the unconfined system in northern Basin A, which probably relate to confined flow system contamination to the Northwest in zones 1U and 1.

4.3.4.2.1 Winter 1987/88 and Water Remedial Investigation Report Comparison. - During the Water Remedial Investigation Report, dithiane/oxathiane concentrations were detected in only 6 of 140 samples analyzed, with concentrations ranging from 1.68 to 312 $\mu\text{g/l}$. Table 4.3-4 summarizes these results for each of the confined flow system zones. The highest concentration during the Water Remedial Investigation Report was detected in a sample from zone 1 in Well 26066, which is located at the western edge of Basin C in Section 26. Concentrations detected in this well decreased from 312 $\mu\text{g/l}$ in the Water Remedial Investigation Report to 141 $\mu\text{g/l}$ for the winter 1987/88 program. The highest concentration during the winter 1987/88 sampling event was detected in a sample obtained from Well 36140 (341 $\mu\text{g/l}$). This well had not been sampled during the Water Remedial Investigation. The discrepancy in the location and magnitude of concentration highs may be largely attributable to changes in the sampling network.

4.3.5 Benzothiazole

Analyses for benzothiazole were conducted on 424 ground-water samples obtained during the winter 1987/88 monitoring event. The CRLs for the various monitoring programs were 2.00 $\mu\text{g/l}$ for Task 44, 1.14 for Task 25, and 5.00 $\mu\text{g/l}$ for the TMP. Above-CRL benzothiazole concentrations ranged from 1.99 to 370 $\mu\text{g/l}$ in 37 samples. Benzothiazole was detected in the confined flow system in 10 of 134 samples from zones A, 1U, 1, 2, 4 and 5. The distribution of benzothiazole in the unconfined ground-water flow system for the winter 1987/88 sampling quarter is illustrated in Figure 4.3-10. Detections above CRLs in both the unconfined and confined systems for the 1988 monitoring program are summarized in Table 4.3-5.

4.3.5.1 Unconfined Flow System. During the winter 1987/88 sampling event, 290 ground-water samples were collected from unconfined wells and analyzed for benzothiazole, which was detected above CRL in 27 of these samples at concentrations ranging from 2.07 to 370 $\mu\text{g/l}$. Benzothiazole plumes were reported in the South Plants, Basin A Neck, and Basin F and Basin F East Pathways (Figure 4.3-10). The highest concentration of benzothiazole was in the South Plants area. Concentrations in excess of 250 $\mu\text{g/l}$ were also observed in the Basin A Neck Pathway (Section 35) and north of Basin F in Section 26.

The benzothiazole plume in the South Plants area extends from northernmost Section 1 to the south approximately 4,000 ft. Concentrations within the plume range from 25.7 to 370 $\mu\text{g/l}$. Migration occurs primarily through the unconfined flow system beneath unsaturated alluvium.

The Basin A Neck plume extends northwest from northern Section 36, about 1,500 ft downgradient. Concentrations within the plume range from 12.5 to 350 $\mu\text{g/l}$, and flow is primarily through areas of saturated alluvium.

The Basin F plume originates at the northeast corner of Basin F and extends downgradient along the Basin F Pathway about 5,000 ft. Concentrations within the plume range from 8.43 to 270 $\mu\text{g/l}$, its flow is through saturated alluvium. A small plume occurs in the Basin F East Pathway, with detections ranging from 9.10 to 14.0 $\mu\text{g/l}$.

4.3.5.1.1 Winter 1987/88 and Water Remedial Investigation Report Comparison. - Benzothiazole was detected in 17 of the 266 samples analyzed for the Water Remedial Investigation Report, as compared to detections in 27 of 290 samples analyzed from the winter 1987/88 event. Distributions were compared between the periods using Figure 4.3-10 of this report and Figure 4.2-7 (Appendix F) of the Water Remedial Investigation Report.

Benzothiazole plumes were observed during both programs in the Basin A and Basin F Pathways. Additional plumes were contoured in the South Plants area and the Basin F East Pathway for the winter 1987/88 sampling event as a result of improved well control. Concentrations ranged from 1.24 to 14.6 $\mu\text{g/l}$ for the Water Remedial Investigation Report and from 2.07 to 370 $\mu\text{g/l}$ for the winter 1987/88 event. The highest concentration reported in the Water Remedial Investigation Report was in the Basin A Pathway (Well 36090). For the winter 1987/88 sampling event, the maximum reported concentration was located in the South Plants plume (Well 01525). Well 36090 had a comparable benzothiazole detection (12.5 $\mu\text{g/l}$) during winter 1987/88, and Well 01525 was not sampled during the Water Remedial Investigation.

Concentration ranges and highs vary considerably for plumes from the two sampling programs. These are as follows:

Plume	Concentration Ranges ($\mu\text{g/l}$)
Basin A Pathway	
Water Remedial Investigation Report	5.27 - 14.6
Winter 1987/88	15.6 - 350
Basin F Pathway	
Water Remedial Investigation Report	3.64 - 12.8
Winter 1987/88	5.97 - 270

Differences in these plumes include an extension of the Basin A plume northwest into the Basin A Neck Pathway (Section 35). The plume may have migrated from north of Basin A into the Basin A Neck Pathway. In addition, the Basin F plume extends over a greater distance, and based on winter 1987/88 data, extends from northern Section 26 (Basin F) into Section 23. The Water Remedial Investigation Report plume covers only a portion of eastern Section 23. The winter 1987/88 data thus indicate more clearly that Basin F's sanitary and chemical sewers, deep injection well, and surface facilities for the well are potential sources in this area. Nine of the wells sampled during the Water Remedial Investigation Report were reported as below the CRL, but during winter 1989/88 showed benzothiazole concentrations above the CRL.

There are significant differences in the high values for plumes between the Water Remedial Investigation Report and the winter 1987/88 events. The high benzothiazole concentration reported in Basin A Neck (350 $\mu\text{g/l}$) was detected in Well 35065 for the winter 1987/88 monitoring event. The concentration in this well was less than the CRL in the Water Remedial Investigation Report. The high benzothiazole detection for the Basin F plume (270 $\mu\text{g/l}$) was detected in Well 26041 during the winter 1987/88 event. This well had a detection of only <40.0 $\mu\text{g/l}$ in the Water Remedial Investigation Report. Disallowing for laboratory errors, continued sampling of the wells in question is required to assess these inconsistencies between sampling results.

4.3.5.1.2 Winter 1987/88 and Initial Screening Program Comparison. - Comparisons of CMP benzothiazole analytical results to Initial Screening Program analytical results cannot be made because benzothiazole is a comparatively new analyte that was not included in the Initial Screening Program list of analytical parameters.

4.3.5.2 Confined Flow System Results. During the winter 1987/88 event, 134 ground-water samples were collected from the confined flow system zones and analyzed for benzothiazole. Of these, 10 wells in zones A, 1U, 1, 2, 4 and 5 had concentrations of benzothiazole. The results of these analyses are summarized in Table 4.3-5 and point plot presentations of the data are shown in Figures A-16 through A-19. Concentrations ranged from 1.99 to 48.4 $\mu\text{g/l}$, with the high

detected in a well completed in zone A and located in the Basin A Neck area. The deepest detection of benzothiazole was at 169 ft below ground level in zone 4 (Well 23193) at a concentration of 12.4 $\mu\text{g/l}$. The deepest stratigraphic occurrence of benzothiazole was in zone 5 (Well 23184) at a concentration of 1.99 $\mu\text{g/l}$ and a depth of 120 ft below ground level. Most of detections were in samples collected from confined flow system zones A and 2.

A downward component of contaminant migration is indicated by comparing confined flow system zones data from different programs and with unconfined flow system benzothiazole data. The concentration high reported in the unconfined system in the Basin A Neck Pathway is interpreted to correlate, through both downward (vertical) and northwestern (lateral) flow, with concentration highs in confined flow system zones A, 1, and 1U in northern Section 35 and south-central Section 26.

4.3.5.2.1 Winter 1987/88 and Water Remedial Investigation Report Comparison. - For the Water Remedial Investigation Report, benzothiazole was detected in 4 of 140 samples analyzed, with concentrations ranging from 1.50 to 3.56 $\mu\text{g/l}$ in samples collected from Denver Formation zones 1U, 1, 4 and 5. The highest concentration reported during the Water Remedial Investigation Report was from Well 35016 completed in zone 1U. This varies from the high concentration detected in zone A (Well 35066) during the winter 1987/88 program. Both high concentrations, however, were detected in the Basin A Neck Pathway in northeastern Section 35. It is significant that the concentration in Well 35016 increased from 3.56 to 14.3 $\mu\text{g/l}$ from the Water Remedial Investigation Report to the winter 1987/88 sampling event, and that the detected concentration in Well 35066 increased from 1.9 $\mu\text{g/l}$ in the Water Remedial Investigation Report to 48.4 $\mu\text{g/l}$ during the winter 1987/88 program. An assessment of hydrogeologic factors contributing to plume changes is limited by the current understanding of mechanisms controlling contaminant migration into the confined flow system.

4.3.6 Organosulfur Compounds

Analyses for one or more of the organosulfur compounds p-chlorophenylmethyl sulfide, sulfoxide and sulfone were performed on 424 ground-water samples obtained during the winter 1987/88 event. The CRLs for the monitoring programs ranged from 1.08 to 4.70 $\mu\text{g/l}$ for Task 44, 1.08 to 2.24 $\mu\text{g/l}$ for Task 25, and 5.69 to 11.5 $\mu\text{g/l}$ for the TMP. Organosulfur compound concentrations above CRLs ranging from 2.54 $\mu\text{g/l}$ to 6320 $\mu\text{g/l}$ were detected in 115 of the samples analyzed. Organosulfur compounds were detected above CRLs in the confined flow system in 15 samples from all zones except zone 1. The distribution of organosulfur compounds in the unconfined ground-water flow system for the winter 1987/88 sampling quarter is presented in

Figure 4.3-11. Detections of the organosulfur compounds in both the unconfined and confined systems for the 1988 monitoring program are summarized in Table 4.3-6.

4.3.6.1 Unconfined Flow System. Ground-water samples from 290 unconfined wells were analyzed for organosulfur compounds. Of these, 100 contained concentrations of organosulfur compounds above CRLs, with concentrations ranging from 2.54 to 6320 $\mu\text{g/l}$. The highest CRL for the three quarters analyzed (11.5 $\mu\text{g/l}$) was used as the lowest isoconcentration value in constructing the contaminant distribution map shown in Figure 4.3-11.

Plumes of organosulfur compounds were detected in the South Plants - Basin A - A Neck Pathway, the Basin F Pathway, and the Northern Off-post Pathway. Smaller plumes are present in the Basin F East and the First Creek Off-post Pathways. In addition, isolated detections were reported in Sections 1, 23, 24, 31 and 33.

The plume in the South Plants - Basin A - A Neck Pathway trends both north and south from a concentration high located in northwestern Section 1. This area coincides with a ground-water mound in the area. Ground water flows radially away from this high. Total concentrations within this plume range from 25.9 to 6320 $\mu\text{g/l}$, with the highest detection reported in Well 01525 located in northwestern Section 1. Contaminant flow occurs in areas of saturated alluvium, except through portions of Sections 1, 2 and 26, where flow is within the unconfined flow system.

The Basin F plume trends north-northeast from Basin F along the Basin F Pathway to the North Boundary Containment System. Total organosulfur concentrations within this plume range from 11.8 to 1160 $\mu\text{g/l}$. The highest concentration was detected in Well 26133 located just northeast of Basin F. High relative concentrations were noted in Well 23052, about 3/4 mi northeast of Basin F. The mechanism for transporting high concentrations of organosulfur compounds to this location is unknown.

A plume downgradient of the North Boundary Containment System extends along the Northern Off-post Pathway and the First Creek Off-post Pathway. Total organosulfur compounds within this plume range from 16.3 to 143 $\mu\text{g/l}$. The highest concentration was detected in Section 13.

4.3.6.1.1 Winter 1987/88 and Water Remedial Investigation Report Comparison. - Organosulfur compound distributions in the unconfined flow system for the Water Remedial Investigation Report and the winter 1987/88 event were compared, using Figure 4.3-11 of this report and Figure 4.2-8 (Appendix F) of the Water Remedial Investigation Report. Organosulfur compound concentrations

above CRLs were detected in 89 of 266 samples analyzed in the Water Remedial Investigation Report and in 100 of 290 samples analyzed for the winter 1987/88 sampling event.

Organosulfur compounds were present in similar areas in both sampling programs. The plumes and their respective concentration ranges are as follows:

Plume	Concentration Ranges (in $\mu\text{g/l}$)
South Plants - Basin A - A Neck Pathway	
Water Remedial Investigation Report	5.98 - 1420
Winter 1987/88	7.38 - 6320
Basin F Pathway	
Water Remedial Investigation Report	6.24 - 2050
Winter 1987/88	3.30 - 1160
Northern Off-post Pathway	
Water Remedial Investigation Report	5.20 - 157
Winter 1987/88	2.54 - 143

The highest Water Remedial Investigation Report concentrations were detected in the Basin F plume, whereas the highest for winter 1987/88 were detected in the South Plants-Basin A plume. Well 26133, which had the highest value (2050 $\mu\text{g/l}$) in the Water Remedial Investigation Report, had a value of 1160 $\mu\text{g/l}$ in the winter 1987/88 program. Well 01525 had the highest concentration (6320 $\mu\text{g/l}$) detected during the winter 1987/88 sampling event, but was not sampled during the Water Remedial Investigation. Thus, this shift in areal concentration highs can be attributed to the addition of Well 01525 to the winter 1987/88 event.

The South Plants - Basin A - Basin A Neck plume is similar for both sampling periods. However, the South Plants portion of the winter 1987/88 plume extends further south into Sections 1 and 2. The addition of 9 wells in the South Plants area during winter 1987/88 has resulted in the increased well control. They all reported concentrations above the CRL which explains the plume extension. The Basin A Neck portion of the plume extends further northwest in the Water Remedial Investigation Report, whereas in the winter 1987/88 the plume just enters into the Basin A Neck. Well 26006, located in Basin D, was reported to have a concentration of 850 $\mu\text{g/l}$ during the Water Remedial Investigation but this well was not sampled for organosulfur compounds in the winter 1987/88 network. Two additional wells, 26071 and 27040, had detections of 5.98 and 6.44 $\mu\text{g/l}$, respectively, during the Water Remedial Investigation Report, but both were reported as below CRL during winter 1987/88. This difference in analytical results is attributed to the reported CRL used for each sampling event: the Water Remedial Investigation Report used 4.7 $\mu\text{g/l}$, and winter

1987/88 used 11.5 µg/l. Thus, except for Well 26006 not being sampled for organosulfur compounds, the plume extension into the Basin A Neck Pathway is due to analytical differences.

The Basin F plume does not show significant variance in configuration or concentrations between sampling periods. One difference is the more southerly extension of the plume in the Water Remedial Investigation Report. Well 26133, which had the highest concentration in both sampling networks, showed a decrease from 2,050 µg/l during the Water Remedial Investigation Report to 1,160 during winter 1987/88. A small, low concentration plume shown in the winter 1987/88 period in the southern Basin F - northern Basin C area was not indicated in the Water Remedial Investigation Report. Isolated detections above the CRL were reported in Sections 1, 23 and 31, as shown in Figure 4.3-11. There is no obvious source for these detections at this point.

4.3.6.1.2 Winter 1987/88 and Initial Screening Program Comparison. - To assess changes in the rate and extent of organosulfur compound migration, comparisons are made between the Initial Screening Program winter 1985/86 Task 4 analytical results and the winter 1987/88 CMP analytical results. These comparisons are somewhat complicated by the lowest isoconcentration contour value for the CMP data (11.5 µg/l), while for the Initial Screening Program data the two lowest values are 1.3 and 10 µg/l. The differences in these isoconcentration values account for the majority of the differences between the CMP plumes and the Initial Screening Program data. The general spatial configuration of both data sets indicates sourcing in the South Plants, with downgradient migration via Basin A-Basin A Neck into the Basin F area and continued migration towards the North Boundary Containment System.

The CMP plume interpretation is not continuous through the Basin A Neck, whereas the Initial Screening Program interpretation is. The Initial Screening Program interpretation shows widespread areas enclosed within 100 µg/l contours. With more well control, the CMP interpretation does not contain the same widespread areas, but this is partly attributable to the CMP use of 50 and 500 µg/l isoconcentration contours.

Both the CMP and Initial Screening Program interpretations indicate that the highest levels of organosulfur contamination are immediately adjacent to and just downgradient of Basin F. However, an assessment of spatial variability resulting from migration over time is not practicable based on a comparison of CMP and Initial Screening Program results.

4.3.6.2 Confined Flow System. Analyses for one or more of the organosulfur compounds, p-chlorophenylmethyl sulfide, sulfoxide and sulfone, were performed on 134 ground-water samples obtained from the confined flow system during the winter 1987/88 monitoring program.

Concentrations ranging from 3.73 $\mu\text{g/l}$ to 79.6 $\mu\text{g/l}$ were detected in 15 of the samples analyzed. All confined flow system zones except zone 1 had detections above CRLs. The deepest detection of organosulfur compounds during winter 1987/88 was at 191 ft below ground level, at a concentration of 6.80 $\mu\text{g/l}$ in Well 33032, completed in zone 7. winter 1987/88 sampling program analytical results are summarized in Table 4.3-6. Confined flow system point plots from the winter 1987/88 analytical results are presented in Figures A-20 to A-23.

4.3.6.2.1 Winter 1987/88 Water Remedial Investigation Report Comparison. - For the Water Remedial Investigation Report, one or more of the organosulfur compounds were reported in only 7 out of 140 confined flow system samples. These were analyzed at concentrations from 1.25 $\mu\text{g/l}$ to 11.9 $\mu\text{g/l}$. The most detections (3) in the Water Remedial Investigation Report in a single zone were from zone A. The highest concentration in the winter 1987/88 sampling program was detected in zone A, whereas the highest concentration for the Water Remedial Investigation Report was detected in zone 2.

Specific variations between winter 1987/88 and the Water Remedial Investigation include Well 36592, which had the highest value (79.6 $\mu\text{g/l}$) in the winter 1987/88 sampling event, yet was not sampled in the Water Remedial Investigation Report. Well 26061, in which the highest concentration was detected in the Water Remedial Investigation (11.9 $\mu\text{g/l}$), was below the CRL (11.5 $\mu\text{g/m}^3$) in the winter 1987/88 event. Low levels of contamination may continue to exist in this area.

4.3.7 Volatile Aromatics

The volatile aromatics group includes benzene (C_6H_6), chlorobenzene (ClC_6H_5), toluene (MEC_6H_5), ethylbenzene (ETC_6H_5) and the xylene group. Chlorobenzene is also an organohalogen, but because of its aromatic structure it is included in this section. Chlorobenzene and benzene are discussed individually later in this section and also in the total volatile aromatics section. Total volatile aromatics were obtained by summing the concentrations of compounds in this group.

Volatile aromatics analyses were performed on 463 ground-water samples obtained during the winter 1987/88 monitoring. The CRLs for the TMP, Task 25, and Task 44 ranged from 0.820 to 3.20, from 0.620 to 2.10, and from 0.580 to 2.47 $\mu\text{g/l}$. Concentrations of total volatile aromatic compounds above CRL ranged from 0.622 to 680,000 $\mu\text{g/l}$ in 180 of these samples. These detections were reported in the unconfined flow system and in all confined flow system zones except zone B. The distribution of total aromatic compounds in RMA ground water for the 1988 monitoring program is summarized in Table 4.3-7.

4.3.7.1 Unconfined Flow System. Altogether, 325 ground-water samples from unconfined wells were analyzed for volatile aromatics. Of these, 126 had concentrations ranging from 0.622 to 680,000 $\mu\text{g/l}$. The highest CRL (3.20 $\mu\text{g/l}$) was used as the lowest contour interval to construct the plume map shown in Figure 4.3-12.

Plumes of volatile aromatics with concentrations above CRLs were present in the Basin A-South Plants Pathway, Western Tier and Rail Classification Yard Pathways, Basin F Pathway, and Northwest and Northern Off-post Pathways.

The Basin A-South Plants plume extends both north and south away from the interpreted point of origin in Section 1. Ground water flows radially away from the ground-water mound in this area, to the North beneath Basin A, and south and west in Sections 1 and 2. Concentrations range from 0.970 to 680,000 $\mu\text{g/l}$, with the highest concentration occurring in Well 01004. This well is located in a tank farm area in the South Plants where a benzene spill occurred in 1948 (Geraghty and Miller, 1984). The plume extends north through the Basin A Pathway and is interpreted to terminate near the Basin A Neck portion of Section 35. Migration is primarily through saturated alluvium, although low contaminant concentrations are noted in the unconfined flow system in zones VC and A. An isolated detection of 4.15 $\mu\text{g/l}$ was reported in Well 36069 in easternmost Section 36; it may be related to reported spills in a small Railyard siding identified as Source 36-19 (Hunter/ESE, 1987b).

The Western Tier/Railyard plume is the result of contaminant flow within two pathways that merge in Section 33. The points of origin are undetermined, although these plumes are downgradient from the Railyard and the southwest RMA boundary, both of which are potential source areas. Concentrations range from 6.00 to 52.8 $\mu\text{g/l}$ and migration is primarily through saturated alluvium.

VOA have also been detected off-post northwest of the Northwest Boundary Containment System. The northwestern plume begins south of the Northwest Boundary Containment System. Concentrations range from 2.20 to 54.4 $\mu\text{g/l}$ and flow within these plumes is entirely within saturated alluvium.

The Basin F plume contamination is interpreted to originate in the Basin F area and extend northeast along the Basin F Pathway to the North Boundary Containment System. Here the plume extends laterally along the boundary system. Migration in the off-post area is through the Northern Off-post Pathway into Section 12. Concentrations within the on-post plume range from 2.23 to 562 $\mu\text{g/l}$ (Well 26133), and flow is primarily through saturated alluvium.

Three plumes are located downgradient of the North Boundary Containment System. The largest plume extends approximately 8,000 ft downgradient of the North Boundary Containment System in the Northern Off-post Pathway. A second plume near the western end of the North Boundary Containment System extends approximately 4,000 ft to the Northwest. The configuration of the smaller plume is probably a function of the well network, as it trends perpendicular to the flow direction of the First Creek Off-post Pathway.

4.3.7.1.1 Winter 1987/88 and Water Remedial Investigation Report Comparison. - VOA distributions in the unconfined flow system for the Water Remedial Investigation Report and the winter 1987/88 sampling events were compared, using Figure 4.3-12 of this report and Figure 4.2-9 (Appendix F) of the Water Remedial Investigation Report. Total aromatics were detected above CRLs in 49 of 331 wells sampled for the Water Remedial Investigation Report, compared to 126 of 325 wells sampled for the winter 1987/88 event. VOA distributions in both sampling events and their respective concentrations are as follows:

Plume	Concentration Ranges (in $\mu\text{g/l}$)
Basin A - South Plants Pathway	
Winter 1987/88	0.970 - 680,000
Water Remedial Investigation Report	2.49 - 56,200
Northwestern Pathway	
Winter 1987/88	2.20 - 54.4
Water Remedial Investigation Report	2.69 - 10.2
Basin F Pathway	
Winter 1987/88	2.23 - 562
Water Remedial Investigation Report	4.67 - >553
Northern Off-post Pathway	
Winter 1987/88	3.47 - 28.7
Water Remedial Investigation Report	2.49 - 28.5

The highest VOA concentration in the Water Remedial Investigation Report was 56,200 $\mu\text{g/l}$, compared to 680,000 $\mu\text{g/l}$ for the winter 1987/88 period. Although there is a significant increase in the maximum concentration reported, both were detected in the South Plants-Basin A plume. Well 36001 contained the highest VOA concentration (56,200 $\mu\text{g/l}$) reported in the Water Remedial Investigation Report, which resulted mainly from the contribution of benzene; the well had a reported detection of 41,000 $\mu\text{g/l}$ during winter 1987/88. The highest VOA concentration (680,000 $\mu\text{g/l}$) during winter 1987/88 was reported in Well 01004, which was not sampled during the Water Remedial Investigation, and both benzene and chlorobenzene contributed to the high concentration.

Wells 36001 and 01004 are separated by about 2,000 ft. The general configuration of the South Plants-Basin A plume is, however, similar for both sampling events. The plume extends further into the Basin A Neck Pathway in the Water Remedial Investigation Report, although this may be the result of using a lower CRL in the Water Remedial Investigation Report (2.47 $\mu\text{g/l}$).

The Northwestern plume is similar in the Water Remedial Investigation Report and winter 1987/88, but occurs entirely off-post in the Water Remedial Investigation Report. Concentration changes in excess of an order of magnitude were noted in wells within this plume. Well 37331 had a concentration of 54.4 $\mu\text{g/l}$ during the winter 1987/88 program, but was below the CRL in the Water Remedial Investigation Report. Conversely, Well 37335 has a concentration of 10.2 $\mu\text{g/l}$ in the Water Remedial Investigation Report, but had a reported concentration of only 1.65 $\mu\text{g/l}$ in the winter 1987/88 program.

Concentrations and basic configurations of the Basin F and Northern Off-post plumes are similar for both the Water Remedial Investigation Report and the winter 1987/88 periods. Differences worthy of note are:

- Winter 1987/88 data show VOAs spreading laterally along the North Boundary Containment System and a lack of contaminant continuity upgradient versus downgradient of the North Boundary Containment System.
- Winter 1987/88 data show a plume trending northwest on the western side of the Northwest Boundary Containment System. Water Remedial Investigation Report data show only an isolated detection of VOAs in this area.
- A plume was shown in the Water Remedial Investigation Report that was about 3,000 ft in length along the First Creek Off-post Pathway. This plume is not represented in winter 1987/88, only immediately south of the First Creek - O'Brian Canal confluence. This difference is probably a function of the lower CRL used in the Water Remedial Investigation Report.

A plume in the Western Tier/Railyard Pathways shown for the winter 1987/88 event is absent in the Water Remedial Investigation Report. Aside from 3 isolated detections in Sections 4 and 33 during the Water Remedial Investigation Report, 5 of the 6 wells making up the plume during winter 1987/88 were reported as below CRL during the Water Remedial Investigation Report.

4.3.7.1.2 Winter 1987/88 and Initial Screening Program Comparison. - For the purposes of assessing temporal data variability that may indicate changes in the rate and extent of VOA migration, Initial Screening Program winter 1985/86 results were compared to the CMP winter 1987/88 results presented in Figure 4.3-12. In the Initial Screening Program Task 4 report, volatile aromatic compound distributions were presented in Figure 3.2-17.

There are several differences between the CMP and Initial Screening Program data interpretations. In the South Plants, more dense CMP well control indicates high VOA concentrations in the south end of the South Plants. Conversely, the Initial Screening Program data interpretation indicates that the high VOA contamination is downgradient of South Plants in the Basin A area.

In both the CMP and Initial Screening Program data interpretations, high VOA concentrations were detected downgradient of Basin F; however, Initial Screening Program data are contoured within a 1000 $\mu\text{g/l}$ isoconcentration contour, and CMP data (from the same wells) are enclosed within a 100 $\mu\text{g/l}$ contour. Unlike the Initial Screening Program interpretation, CMP data indicate VOA contamination extending downgradient to the North Boundary Containment System. The Task 25 data included in the winter 1987/88 CMP interpretation provide much more densely spaced information for the North Boundary Containment System area than was presented in the Initial Screening Program database. Similarly, VOA migration off-post in the northwest quadrant of Section 23 is indicated by the CMP data, but the Initial Screening Program network did not include this area.

VOA detections in the Western Tier are contoured in the Initial Screening Program as two isolated masses, whereas the CMP interpretation shows a single large plume enclosed within a 10 $\mu\text{g/l}$ contour. In the Western Tier, Initial Screening Program well coverage was more dense than was the CMP well coverage. The differences may indicate contaminant migration in the area.

Initial Screening Program data in the vicinity of the Northwest Boundary Containment System indicate one isolated detection, whereas the more densely spaced CMP data in this area indicate contamination migrating southwest of the Northwest Boundary Containment System. Similar CMP interpretations of contaminant migration (Dieldrin, Endrin) in the vicinity of the Northwest Boundary Containment System may indicate contaminant migration in the area. It is important to note, however, that the differences in Initial Screening Program and CMP monitoring networks in the Northwest Boundary Containment System area may account for the variability attributed to possible contaminant flow. Continued monitoring should permit an assessment of the reason for the apparent differences in contaminant distribution.

4.3.7.1.3 Winter 1987/88 and Spring and Summer 1988 Comparison. - Data for the spring and summer 1988 monitoring programs are summarized in Table 4.3-7. Differences noted between the winter 1987/88 and spring 1988 events are listed below:

1. The Basin A - South Plants plume extends further west along the Basin A Neck for the spring 1988 compared to the winter 1987/88 plume;
2. The plume downgradient of the North Boundary Containment System in the spring 1988 program includes only a small extension at the bend of the boundary system;
3. Both the Western Tier and the Northwestern plumes are smaller in spring 1988 (Figure 4.3-13) than those noted for winter 1987/88;
4. Spring 1988 data indicate a plume may exist in Section 9 of the RMA which was not indicated on the winter 1987/88 contaminant distribution map.

Data collected for the summer 1988 sampling event yielded results in the Basin F area that are similar to those from the winter 1987/88 program. The data are shown in Table 4.3-8. The noted exceptions are in Wells 23049 and 26041. The respective concentrations during winter 1987/88 were 70.0 and 132 $\mu\text{g/l}$, but below CRL and 15.6 $\mu\text{g/l}$ during summer 1988.

4.3.7.1.4 Confined Flow System. - Total volatile aromatic analyses were performed on 138 samples, with 54 detections ranging from 1.11 to $>450 \mu\text{g/l}$. Benzene and chlorobenzene are the most frequently detected compounds in the total volatile aromatic group. The majority of above-CRL detections were in samples from confined flow system zones A, 1U, 1, 2, 4 and 5. Zones VC, 3, 6 and 7 had only one above-CRL detection each, and zone B had no detections. The deepest detection of volatile aromatics during winter 1987/88 was 191 ft below ground level at a concentration of 323 $\mu\text{g/l}$ in Well 33032, completed in zone 7. Analytical results for the confined flow system from winter 1987/88, spring 1988, and summer 1988 programs are summarized in Table 4.3-7. Selected point plots from the sampling programs cited above are presented in Figures A-24 through A-38.

The presence of volatile organics in most confined flow system zones generally can be associated with contamination in the overlying unconfined flow system. However, areas exist in some zones where overlying contamination of the unconfined flow system does not relate clearly to confined flow system contamination. Some examples are given below:

1. Well 36592 had reported VOA sums above 450 $\mu\text{g/l}$ in zone A, higher than that in the unconfined system above it. This contamination is probably the result of vertical flow at or near its source combined with lateral migration in Denver sand(s) to the Northeast.
2. Well 35012, at a total VOA concentration of 90.8 $\mu\text{g/l}$ in zone 1U, is higher than overlying unconfined VOA concentrations. This is probably the result of combined vertical and northwestern lateral flow from the Basin A area. It is also possible that contaminants in the overlying unconfined system have been flushed or migrated past this point.
3. VOAs in confined flow system zone 2 in the area of the North Boundary Containment System, reported at concentrations of 173 and 208 $\mu\text{g/l}$, exceed VOA concentrations in any nearby unconfined or stratigraphically higher confined flow system zones.

4.3.7.1.5 Winter 1987/88 and Water Remedial Investigation Report Comparison. - For the Water Remedial Investigation Report, 141 confined flow system wells were analyzed for total volatile aromatics, which resulted in 32 detected concentrations above CRL. As in the winter 1987/88 analyses, the Water Remedial Investigation Report results show that benzene and chlorobenzene are detected most frequently. Data were not presented for summed VOAs in the Water Remedial Investigation Report; therefore, further temporal comparisons of VOAs in the regional networks were not made. Concentrations above CRLs of VOAs are reported in similar locations both in the Water Remedial Investigation Report and in the winter 1987/88 event.

4.3.7.1.6 Winter 1987/88 and Spring and Summer 1988 Comparison. - During spring 1988, 32 of 87 samples analyzed had VOA concentrations ranging from 1.05 to >81,700 $\mu\text{g/l}$. Comparison of results from the winter 1987/88 and the spring 1988 events reveals that where the same wells were sampled, they generally compared reasonably well. Some exceptions exist, such as in Section 3, where the VOA sum was 49.5 $\mu\text{g/l}$ during spring 1988 and no detection was reported during the winter 1987/88 event. These cases occur for fairly low concentrations, those not exceeding 49.5 $\mu\text{g/l}$. This may therefore be the result of analytical variability for the individual VOA compounds. During spring 1988, the deepest volatile aromatic detection (6.92 $\mu\text{g/l}$) was at 183 ft below ground level in Well 04012, completed in zone 6.

During the summer 1988 event 4 of 20 samples had VOA detections ranging from 3.49 to 11.3 $\mu\text{g/l}$. Zones 1 through 4 were sampled but only zones 1 and 2 showed VOA detections. Table 4.3-8 lists the quarterly specific area monitoring results for the three sampling events.

4.3.7.2 Benzene. Benzene analyses were performed on 431 ground-water samples obtained during the winter 1987/88 monitoring event. The CRLs for Task 44, Task 25 and TMP were 1.10 to 1.92, 1.92 and 1.70 $\mu\text{g/l}$. Concentrations ranging from 1.79 to 680,000 $\mu\text{g/l}$ were detected in 70 of these samples. Benzene was detected in all of the Denver Formation zones except in zones B and 6. Detections in both the unconfined and confined systems for the 1988 monitoring program are summarized in Table 4.3-9.

4.3.7.2.1 Unconfined Flow System. - A total of 301 ground-water samples from unconfined wells were analyzed for benzene. Of these, 48 had concentrations ranging from 2.00 $\mu\text{g/l}$ to 680,000 $\mu\text{g/l}$. The highest CRL for the three sampling events (1.92 $\mu\text{g/l}$) was used as the lowest isoconcentration value in constructing the contaminant distribution map shown in Figure 4.3-14.

Benzene occurs primarily in three areas: South Plants-Basin A, Basin F to the North Boundary Containment System and in the Irondale Containment System area. Isolated detections are noted north and northwest of the RMA boundary and in Section 24.

The plume in the South Plants-Basin A area has a maximum reported concentration of 680,000 $\mu\text{g/l}$, (Well 01004). This well is near the tank farms where a benzene spill occurred in 1948, and appears to be a point of origin for this plume (Geraghty & Miller, 1984). The plume extends southwest in the direction of ground water flow. Benzene from spills and leaks in other areas of South Plants migrates north across Basin A toward the Basin A Neck area. Flux occurs in saturated alluvium, except through Section 1, where flux is through the unconfined Denver Formation.

The Irondale plume occurs almost entirely within Section 33, and concentrations above CRL range from 4.11 to 33.0 $\mu\text{g/l}$. The point of origin for this plume is unclear. Benzene occurs entirely within saturated alluvium in this area.

The Basin F plume is interpreted to originate in the Basin F area and follow the Basin F Pathway to the North Boundary Containment System. The highest concentration detected in this plume is 510 $\mu\text{g/l}$ detected in Well 26133, located just northeast of Basin F. Flux occurs primarily through saturated alluvium except in northern Section 26.

4.3.7.2.2 Winter 1987/88 and Water Remedial Investigation Report Comparison. - Comparison of benzene distributions in the unconfined flow system for winter 1987/88 and Water Remedial Investigation Report was performed using Figure 4.3-14 of this report and Figure 4.2-10 of the Water Remedial Investigation Report. In the Water Remedial Investigation Report, 331 samples were analyzed for benzene which resulted in 36 detections, compared to 48 detections in 301 wells in winter 1987/88. The two major benzene plumes are in the South Plants and Basin F areas for both sampling periods. Concentrations in the Basin F plume are generally the same, although the Water Remedial Investigation Report plume extends further to the Southeast than does the winter 1987/88 plume. Concentrations in the South Plants plume increased from a high of 25,000 $\mu\text{g/l}$ (Well 36001) in the Water Remedial Investigation Report to 680,000 $\mu\text{g/l}$ (Well 01004) for the winter 1987/88 sampling event, but the plume configuration was similar for both periods. Well 36001 was not sampled for benzene during winter 1987/88, and Well 01004 was not sampled during the Water Remedial Investigation. Some notable differences between the two sampling events are the absence of a benzene plume in the Irondale area in the Water Remedial Investigation Report that was shown during winter 1987/88, and the occurrence of benzene in the Northern Off-post Pathway in the Water Remedial Investigation Report that was not shown in the winter 1987/88. The 10 wells making up the plume in the Irondale area were sampled for the Water Remedial Investigation Report but were reported as below the CRL during winter 1987/88. Five wells within the plume in the Northern Off-post Pathway in the Water Remedial Investigation Report were sampled during winter 1987/88, but were reported as below the CRL.

4.3.7.2.3 Winter 1987/88 and Initial Screening Program Comparison. - Comparisons are made between the winter 1985/86 Initial Screening Program results (ISP Report, Figure C-13) and the winter 1987/88 CMP results (Figure 4.3-14) for the purposes of assessing changes in the rate and extent of benzene migration.

Both the CMP and Initial Screening Program data interpretations are generally similar in that benzene contamination is identified in the South Plants - Basin A area, Basin F - North Boundary Containment System area, and the Western Tier. Specifics of the interpretations are substantially different in that the CMP interpretation (based on more well control) shows that benzene contamination is considerably more extensive in both the South Plants - Basin A area and the Basin F - North Boundary Containment System area. Not all these differences can be attributed to increased CMP well control, however, because low concentrations of benzene identified at the North Boundary Containment System in the CMP occur in areas that have adequate Initial Screening Program well coverage. Contaminant migration in this area may therefore be the source of this variability.

Another difference between CMP and Initial Screening Program interpretations occurs in Sections 4 and 33 of the Western Tier. The Initial Screening Program data distribution indicates a small, contoured mass of benzene contamination localized in the northeast corner of Section 4, downgradient of the Railyard. Two other widely-space isolated benzene detections occur in the Initial Screening Program data. Initial Screening Program well coverage was greater in the Western Tier than in the CMP. The CMP interpretations, however, present a large area of Sections 4 and 33 containing low-level benzene contamination. Widespread, low-level benzene contamination in the RMA Western Tier may indicate contaminant migration in the area.

4.3.7.2.4 Confined Flow System. - Of 130 samples analyzed for benzene in the confined flow system, 22 had detections ranging from 1.79 to 250 $\mu\text{g/l}$. The majority of detections occur near the North Boundary Containment System in zones 2, 3 and 4. An area of high concentration, however, is located east of Basin A in zone A. The contamination in this location is probably the result of vertical migration at or near the source followed by lateral flow to the Northeast.

The deepest benzene contamination in the confined flow system occurs at 191 ft below ground level in Well 33032 (250 $\mu\text{g/l}$), completed in zone 7. Winter 1987/88 event analytical results are summarized in Table 4.3-9. Point plots from the winter 1987/88 analytical results are presented in Figures A-39 through A-44.

4.3.7.2.5 Winter 1987/88 and Water Remedial Investigation Report Comparison. - For the Water Remedial Investigation Report, benzene was detected in 27 of 144 samples analyzed, with concentrations ranging from 1.63 to 73.8 $\mu\text{g/l}$. As with the winter 1987/88 data, the majority of detections occurred in zones 2, 3 and 4 just north of the North Boundary Containment System. Notable differences are a change in areas of highest concentration from Basin A for the winter 1987/88 program to off-post Section 14 in the Water Remedial Investigation Report. This cannot be attributed entirely to a change in the sampling network. For example, Well 37387, for which the high was detected in the Water Remedial Investigation Report, is below detection in the winter 1987/88 data. Conversely, Well 33032, for which the high was detected in winter 1987/88, was below detection in the Water Remedial Investigation Report.

4.3.7.3 Chlorobenzene. Chlorobenzene analyses were performed on 453 ground-water samples collected during the winter 1987/88 monitoring program. The CRLs for the various monitoring programs were 0.820 $\mu\text{g/l}$ for the TMP, 1.36 $\mu\text{g/l}$ for Task 25, and 0.580 and 1.36 $\mu\text{g/l}$ for Task 44. Chlorobenzene concentrations ranging from 0.620 to 41,000 $\mu\text{g/l}$ were reported in 154 samples. Chlorobenzene was reported in all confined flow systems except zone B. Detections above the CRL

in both the unconfined and confined flow systems for the winter 1987/88 monitoring program are summarized in Table 4.3-10.

4.3.7.3.1 Unconfined Flow System. - Chlorobenzene concentrations above the CRL were detected in 108 of 317 ground-water samples from unconfined wells. Concentrations ranged from 0.620 to 41,000 $\mu\text{g/l}$. The highest CRL (1.36 $\mu\text{g/l}$), was used to construct the contaminant distribution map shown in Figure 4.3-15 of this report.

Chlorobenzene was detected above CRLs in the South Plants-Basin A Pathway, the Western Tier Pathway, Basin F Northwest and Northern Off-post Pathways. A small plume is located in the First Creek Off-post Pathway.

The South Plants-Basin A plume originates in the South Plants area and extends both north across Basin A and south across northwestern Section 1 into Section 2. Reported concentrations in this plume range from 0.970 to 41,000 $\mu\text{g/l}$. The area of highest concentration is located in southwest Section 36, just downgradient from South Plants. Flow is primarily through saturated alluvium, however some contaminant transport through the unconfined Denver Formation is observed through Section 1.

The Western Tier plume flows north through portions of Sections 4 and 33. This plume was drawn with limited well control and the configuration is therefore inferred. The range of concentration is from 17.6 to 44.1 $\mu\text{g/l}$ and flow occurs through areas of saturated alluvium.

The Basin F Northwestern plume is detected south of the Northwest Boundary Containment System and narrows as it nears the RMA boundary. Chlorobenzene contamination has also been detected off-post northwest of the Northwest Boundary Containment System. Concentrations range from 1.65 $\mu\text{g/l}$ to 28.1 $\mu\text{g/l}$ and flow appears to be primarily through saturated alluvium.

The Basin F plume is interpreted to originate just north of Basin F and migrates northeast along the Basin F Pathway to the North Boundary Containment System, where it spreads out laterally along the south side of the boundary system. Concentrations in this plume range from 1.37 to 70.0 $\mu\text{g/l}$, with the highest levels reported in Section 26 just northeast of Basin F. Flow is primarily through areas of saturated alluvium.

The Northern Off-post plume extends about 7,000 ft from the North Boundary Containment System through Section 13 and into Section 12. Concentrations range from 1.72 to 28.7 $\mu\text{g/l}$ and migration is primarily through areas of saturated alluvium.

4.3.7.3.2 Winter 1987/88 and Water Remedial Investigation Report Comparison. - Chlorobenzene plumes identified in the Water Remedial Investigation Report and during the winter 1987/88 event were compared using Figure 4.3-15 of this report and Figure 4.2-12 (Appendix F) of the Water Remedial Investigation Report. Chlorobenzene concentrations above CRLs were detected in 52 of 331 samples analyzed in the Water Remedial Investigation and in 108 of 317 samples analyzed in winter 1987/88 sampling event. The range of reported concentrations for the Water Remedial Investigation Report is 0.582 to 31,200 $\mu\text{g/l}$, whereas the range for winter 1987/88 is 0.620 to 41,000 $\mu\text{g/l}$. Although the range is similar between sampling periods, concentrations are generally higher for winter 1987/88. Chlorobenzene was detected in 108 samples during winter 1987/88. During the Water Remedial Investigation Report, 47 of the 108 samples were below CRLs, and 25 were not analyzed. Many of these concentration differences are significant. For example, Well 23049 had a reported concentration of 70.0 $\mu\text{g/l}$ in winter 1987/88, compared to below CRL in the Water Remedial Investigation Report. These discrepancies cannot be attributed solely to network changes, but probably include other factors such as sampling, analytical variability, or natural phenomena associated with contaminant migration.

Major chlorobenzene occurrences reported in both sampling events include the South Plants-Basin A Pathway, the Northwest Basin F Pathway and the Northern Off-post Pathway. The variations in concentration ranges between sampling events are as follows:

Plume	Concentration Ranges ($\mu\text{g/l}$)
South Plants - Basin A Pathway	
Water Remedial Investigation Report	0.980-31,200
Winter 1987/88	0.970-41,000
Northwestern Pathway	
Water Remedial Investigation Report	2.69-8.55
Winter 1987/88	1.65-28.1
Northern Off-post Pathway	
Water Remedial Investigation Report	2.42-22.7
Winter 1987/88	1.72-28.7

Differences in the plumes in the Water Remedial Investigation Report versus winter 1987/88 include:

1. The extension of the Basin A plume farther into the Basin A Neck Pathway;
2. The lack of plume extension to the south into Section 1 in the South Plants;

3. The absence of a plume in off-post Section 3 in winter 1987/88; and
4. The almost exclusively off-post location of the Northwestern plume during the Water Remedial Investigation Report.

Two plumes were contoured for the winter 1987/88 event (Figure 4.3-15) in the Western Tier and the Basin F Pathways that are not present on the Water Remedial Investigation Report maps. In the Western Tier, 4 isolated detections were reported in the Water Remedial Investigation Report and were contoured as a plume for the winter 1987/88 event. Six more wells included in the Basin F plume were sampled during winter 1987/88, but were not sampled during the Water Remedial Investigation Report. However, those wells making up the Basin F Pathway plume that were sampled under both programs are consistently reported as below the CRL during the Water Remedial Investigation Report.

4.3.7.3.3 Winter 1987/88 and Initial Screening Program Comparison. - For the purposes of assessing temporal data variability that may be attributable to contaminant flow, winter 1987/88 CMP data interpretations (Figure 4.3-15) are compared to winter 1985/86 Initial Screening Program data interpretations (ISP Report, Figure C-24). In the South Plants - Basin A area, the interpretations are very similar, with the highest chlorobenzene detections located near Well 36001.

In the Basin F - North Boundary Containment System area, increased CMP well coverage allowed a more detailed assessment of chlorobenzene contamination downgradient of Basin F. Nevertheless, Initial Screening Program well coverage existed near the North Boundary Containment System but did not yield detectable concentrations of chlorobenzene. Relatively low concentrations of chlorobenzene at the North Boundary Containment System may be indicative of monitoring program variability.

Similarly, the CMP interpretation indicates widespread, low-level chlorobenzene contamination in the Northwest Boundary Containment System vicinity. The fact that no chlorobenzene was detected near the Northwest Boundary Containment System in the Initial Screening Program appears largely attributable to sparse Initial Screening Program well coverage in the area. This is also true of a small CMP chlorobenzene plume in Section 4 of the Western Tier that is not present in the Initial Screening Program interpretation. Well network differences appear to account for the interpretative differences in the Western Tier.

4.3.7.3.4 Confined Flow System. - Chlorobenzene analyses were performed on 136 ground-water samples from the confined flow system, resulting in 46 sample concentrations above CRL detections during the winter 1987/88 monitoring event. Concentrations ranged from 1.06 to >200 $\mu\text{g/l}$, with detections reported in zones VC, A, 1U and 1 through 7. High concentrations were reported in zone 2 near the North Boundary Containment System. Analytical results for the Denver Formation are summarized in Table 4.3-10 and point plots of chlorobenzene detections are shown in Figures A-45 through A-49.

The deepest chlorobenzene detection in the confined flow system was in zone 7 in Well 33032 at a depth of 191 ft below ground level and a concentration of 40.3 $\mu\text{g/l}$.

Chlorobenzene observed in confined flow system zones may generally be readily associated with contamination in the unconfined flow system. Notable exceptions to this occur in the vicinity of the North Boundary Containment System. In zone 2, chlorobenzene was observed in two wells at concentrations above 160 $\mu\text{g/l}$. The origin of this contamination is unclear, particularly because detections of this contaminant in the confined system above 160 $\mu\text{g/l}$ occur only as far north as Section 36. High detections noted in zones 3 and 4 are also of unknown origin.

During the CMP semiannual sampling conducted in spring 1988, a detection of 79,000 $\mu\text{g/l}$ was recorded in Well 36182.

4.3.7.3.5 Winter 1987/88 and Water Remedial Investigation Report Comparison. - In the Water Remedial Investigation Report, chlorobenzene detections above CRL were reported in 24 of 144 confined flow system wells sampled, with concentrations ranging from 0.790 to 74.7 $\mu\text{g/l}$ (Table 4.3-10). The majority of these detections occur in Denver Formation zones 2, 3 and 4. The highest concentration areas are located off-post just north of the North Boundary Containment System in Section 14. Off-post wells sampled in this same area for the winter 1987/88 program similarly showed high levels of chlorobenzene. Of note is that Well 36110, for which a high value of >200 $\mu\text{g/l}$ was detected during the winter 1987/88 sampling event, was not detected during the Water Remedial Investigation Report. This well has historically recorded chlorobenzene concentrations below the CRL, and thus the change can probably be attributed to sampling or laboratory errors. Well 37387, for which the maximum concentration (74.7 $\mu\text{g/l}$), was detected during the Water Remedial Investigation Report, showed no detection for the winter 1987/88 sampling event. This well has not been sampled historically.

4.3.8 Volatile Organohalogens

Compounds included in the volatile organohalogen group are:

- 1,1-Dichloroethlyene
- 1,1-Dichloroethane
- 1,2-Dichloroethane
- 1,1,1-Trichloroethane
- 1,1,2-Trichloroethane
- Carbon Tetrachloride
- Chloroform
- Methylene Chloride
- Trans-1,2-Dichloroethlyene
- Tetrachloroethlyene
- Trichloroethlyene

Total organohalogen concentrations were obtained by summing the concentrations of compounds in this group. Chloroform, tetrachloroethlyene (TCLEE) and trichloroethlyene (TRCLE) are included in this group and are also discussed separately later in this report.

Ground-water samples from 459 wells were analyzed during the winter 1987/88 sampling round for compounds in the volatile organohalogens group. The range of CRLs encompassing the 11 compounds for the TMP, Task 25, and Task 44 are 0.500 to 7.40 $\mu\text{g/l}$, 1.09 to 2.76 $\mu\text{g/l}$ and 0.610 to 5.00 $\mu\text{g/l}$, respectively. Two hundred and seventy-eight (278) wells contained concentrations of organohalogens above the CRL, with total concentrations ranging from 0.568 to 463,000 $\mu\text{g/l}$. Organohalogens were found in the saturated alluvium and in all Denver Formation zones. Table 4.3-11 summarizes the detections in the unconfined and confined systems for the FY88 monitoring program.

4.3.8.1 Unconfined Flow System. Ground-water samples from 322 unconfined wells were analyzed for volatile organohalogens. Of the samples, 223 had above-CRL concentrations ranging from 0.568 to 463,000 $\mu\text{g/l}$. The highest CRL, 7.40 $\mu\text{g/l}$, was used as the lowest contour value in constructing the plume map shown in Figure 4.3-16.

Three plumes of volatile organohalogens are noted on the RMA, and one plume extends off-post. Isolated detections occur both on and off-post. The plumes are: the western RMA boundary area

plume, South Plants - Basin A - Central Pathway plume, the Basin F - North Boundary Containment System plume, and the northern off-post plume.

The South Plants - Basin A - Central Pathway plume had the highest concentrations of all the plumes. Concentrations ranged from 0.610 to 463,000 $\mu\text{g/l}$ (Well 36109) for this plume. The highest concentrations are generally located in the South Plants area, or between the South Plants and Basin A. The plume exhibits a small southwestern extension near Ladora Lake and a larger extension north of the South Plants area. The northern extension continues through Basin A and migrates through the Basin A Neck Pathway to the Northwest Boundary Containment System. There are two inferred plumes in the Central North and South Pathways which combine with the main plume near the Northwest Boundary Containment System. There is also an inferred plume located off-post at the Northwest Boundary Containment System.

An organohalogen plume with concentrations ranging from 1.05 to 127 $\mu\text{g/l}$ is located along the western boundary of RMA. The source (or sources) of this plume is uncertain; however, it may originate off-post to the South. The plume migrates northward along the Western Tier paleochannel, is joined by an extension apparently originating in Section 4, possibly from the Motor Pool. The plume dissipates in Section 33, south and east of the RMA boundary. Flow is primarily through saturated alluvium, except for an isolated occurrence in the unconfined flow system in Section 4.

Organohalogen detected in the Basin F area exhibit concentrations ranging from 0.640 $\mu\text{g/l}$ to 14,100 $\mu\text{g/l}$. Migration in this area is primarily through saturated alluvium. The contaminants extend from Basin F along a north/northeast trend to the North Boundary Containment System. South of the North Boundary Containment System, the plume extends laterally to the east.

A small organohalogen plume is also located in the northwestern portion of Section 2. There is also an isolated VOH detection in western Section 35.

North of the North Boundary Containment System, a plume extends northward through the Northern Off-post Pathway. There is also an extension of this plume to the West in the First Creek Off-post Pathway. The highest VOH concentrations in this plume were observed in off-post Section 12. The plume configuration indicates that the operation of the North Boundary Containment System has disrupted the plume.

Isolated VOH detections below the lowest contour interval, but above the lowest CRL for the compounds comprising the VOHs, are in the vicinity of the three major plumes and are probably

associated with these plumes. There are several isolated VOH detections above individual compound CRLs in Sections 1, 2, 11, 24, 25, 36 and off-post. Total concentrations range from 8.34 to 80.1 $\mu\text{g/l}$. There are no obvious sources associated with these isolated detections.

4.3.8.1.1 Winter 1987/88 and Water Remedial Investigation Report Comparison. - A comparison of this report to the Water Remedial Investigation Report (Figure 4.2-14 Appendix F) reveals few differences in plume configuration except at the western boundary plume. EPA (FY87) off-post data have been shown in the Water Remedial Investigation Report that allow extension of this plume approximately 1 to 2 mi past the RMA boundary to the West. These data were not available for the winter 1987/88 evaluations.

The northern extension of the Western Tier plume is left open at the RMA boundary in Figure 4.2-14 of the Water Remedial Investigation Report, but is inferred as closed within the boundary in Figure 4.3-16. The difference results from a lack of well control during the winter 1987/88 sampling period, for which an accurate depiction of the northern extension of this plume is not possible at this time.

The plume off-post at the RMA north boundary in the First Creek Pathway does not extend to the confluence of First Creek and O'Brian Canal in the Water Remedial Investigation Report. In contrast, winter 1987/88 data indicate that the plume does extend that far.

4.3.8.1.2 Winter 1987/88 and Initial Screening Program Comparison. - Comparisons are made between the Initial Screening Program Task 4 winter 1985/86 data interpretations (Initial Screening Program Report, Figure 3.2-20) and the winter 1987/88 CMP interpretation (Figure 4.3-16) to assess changes in the distribution of volatile organohalogen (VOH) compounds that may be attributable to migration.

Both Initial Screening Program and CMP interpretations have high detected concentrations located in the South Plants-Basin A area and just downgradient of Basin F. Concentrations, however, appear much higher in the CMP interpretation because of the higher isoconcentration contours used to contour the data. The highest isoconcentration value used in the Initial Screening Program was 1,000 $\mu\text{g/l}$, whereas in the CMP it was 100,000 $\mu\text{g/l}$; actual data values are similar in both programs.

Significant differences between the two interpretations include much more widespread Western Tier VOH contamination presented in the CMP than in the Initial Screening Program despite similar well coverage. Scattered, low-level VOH detections in the CMP data in Western Tier Sections 28, 33

and 34 may indicate VOH contaminant migration. Numerous other factors affecting data variability, however, make this a tenuous assessment. Additionally, the CMP Western Tier interpretation indicates off-post sourcing of VOH constituents and this interpretation post-dates the Initial Screening Program.

4.3.8.1.3 Winter 1987/88 and Spring and Summer 1988 Comparison. - Comparisons between winter 1987/88 (Figure 4.3-16) and spring 1988 (Figure 4.3-17) show some differences. One difference is the lack of the Central North and South Pathway extensions from the main plume near the Northwest Boundary Containment System, which is a function of not having specific area monitoring in these locations. Another difference is that a small plume was noted in the North Plants during spring 1988 monitoring that was not shown during winter 1987/88, which probably results from changes in the well network.

Data collected for the summer 1988 event yielded results in Basin F that are similar to those for the winter 1987/88 event. The data for winter 1987/88 and spring and summer 1988 are shown in Table 4.3-12.

4.3.8.2 Confined Flow System. During the winter 1987/88 sampling period, 55 of 137 samples had VOH detections ranging from 0.626 to >1660 $\mu\text{g/l}$. Detections above CRLs were reported in all Denver Formation zones.

Although detections above CRLs were reported in all zones, the highest concentration was reported in zone A (>1660 $\mu\text{g/l}$ in Well 36592). The deepest detection of volatile organohalogenes during winter 1987/88 was at 191 ft below ground level, at a concentration of 484 $\mu\text{g/l}$ in Well 33032, completed in Denver zone 7.

Analytical results for the confined flow system from the winter 1987/88, spring 1988, and summer 1988 events are summarized in Table 4.3-11. Selected point plots from the sampling programs cited above are presented in Figures A-50 through A-64.

4.3.8.2.1 Winter 1987/88 and Spring and Summer 1988 Comparisons. - During the spring 1988 event, 31 of 88 samples had VOH detections ranging from 1.05 to 114,000 $\mu\text{g/l}$. Detections were reported in zones A through 7. The highest concentration was again reported in zone A (114,000 $\mu\text{g/l}$ in Well 36182). The two wells for the winter 1987/88 and spring 1988 sampling periods that had the highest reported VOH detections above the CRL, Wells 36592 and 36182, were not sampled during both periods, so no comparison can be made. During spring 1988, the deepest detection of volatile organohalogenes (111 $\mu\text{g/l}$) was at 172 ft below ground level in Well 03004, completed in

zone 4. The lowest stratigraphic unit containing VOH was zone 7, in which Well 33026 had a reported VOH concentration of 3.99 $\mu\text{g/l}$. Well 33032, which contained the deepest detection of VOH during winter 1987/88, was reported below CRL during spring 1988.

During the summer 1988 event, 5 of 20 samples had VOH detections ranging from 0.650 to 49.5 $\mu\text{g/l}$. Zones 1 through 4 were sampled, and only zones 1 and 2 showed VOH detections above the CRL, with zone 1 reporting the highest detection (49.5 $\mu\text{g/l}$ in Well 26140). Well 26140 was also sampled during the winter 1987/88 event and reported a VOH concentration of 40.1 $\mu\text{g/l}$. Table 4.3-12 lists the quarterly specific area monitoring results for the three sampling events.

4.3.8.3 Chloroform. Chloroform analyses were performed on 455 ground-water samples obtained during the winter 1987/88 monitoring event. The CRLs for the various monitoring programs (in $\mu\text{g/l}$) were 0.500 for the TMP, 1.88 for Task 25, and 1.40 for Task 44. Chloroform concentrations ranging from 0.570 to 460,000 $\mu\text{g/l}$ were reported in 207 of the samples analyzed. Chloroform in the confined flow system included 36 samples from zones B, VC, A, IU and 1 through 7. Chloroform detections above CRL in both the unconfined and confined systems for FY88 are summarized in Table 4.3-13.

4.3.8.3.1 Unconfined Flow System. - A total of 319 ground-water samples from unconfined wells were analyzed for chloroform. Of these, 171 contained chloroform above the CRL ranging in concentration from 0.570 $\mu\text{g/l}$ to 460,000 $\mu\text{g/l}$. The highest CRL for the three quarters (1.88 $\mu\text{g/l}$) was used in constructing the contaminant distribution map shown in Figure 4.3-18.

Large chloroform plumes were detected in the South Plants-Basin A-A Neck Pathway, the Central Pathway, Basin F and Basin F East Pathway, and the Northern Off-post Pathway. Smaller plumes occur in the Railyard, in the Northwest Pathway, and in Section 3. Isolated detections occur in several areas, both on-post and off-post.

The chloroform plume in the Basin A-South Plants area extends both north and south from a concentration high located in southwestern Section 36. Ground-water flow and contaminant migration are distributed radially away from a ground-water mound in the South Plants area both to the North and the South. To the south, the plume extends into portions of Section 1 and 2. To the North, the plume extends into the Basin A Neck Pathway in the northeast portion of Section 35. Concentrations in this plume range from 2.90 $\mu\text{g/l}$ to 460,000 $\mu\text{g/l}$. Chloroform migration occurs through areas of saturated alluvium, except in portions of Sections 1 and 2, where migration occurs primarily through the unconfined Denver Formation.

The plumes in the Central Pathway are located within the Central North and Central South Pathways in Sections 34 and 27, and in the northwestern part of the Basin A Neck Pathway. The three plumes merge in Section 27 near the Northwest Boundary Containment System. Reported concentrations within this plume range from 2.02 $\mu\text{g/l}$ to 68.8 $\mu\text{g/l}$. Contaminant flow occurs predominantly through saturated alluvium.

The Basin F-Basin F East plume flows north along the Basin F East Pathway and merges with the Basin F plume. It then flows northeast to the North Boundary Containment System. Concentrations range from 2.00 $\mu\text{g/l}$ to 63,000 $\mu\text{g/l}$, with the highest levels concentrated just north of Basin F in Section 26. Concentrations generally decrease toward the North Boundary Containment System, although there is a concentration high at Well 26133, approximately 1,000 ft northeast of Basin F.

Chloroform is present north of the North Boundary Containment System in a plume in the Northern Off-post Pathway. The Northern Off-post plume extends north about 8,000 ft from the RMA boundary through Section 13 and into Section 12. Concentrations range from 2.42 $\mu\text{g/l}$ near the North Boundary Containment System to 1180 $\mu\text{g/l}$ in Section 12. Flow is primarily through areas of saturated alluvium.

4.3.8.3.2 Winter 1987/88 and Water Remedial Investigation Report Comparison. - Chloroform distributions in the unconfined flow system for the Water Remedial Investigation Report and the winter 1987/88 event were compared using Figure 4.3-18 and Water Remedial Investigation Report Figure 4.2-15 (Appendix F). Chloroform was present above CRLs in 128 of 332 samples analyzed in the Water Remedial Investigation Report and in 171 of 319 samples analyzed for the winter 1987/88 sampling event.

Concentrations in chloroform plumes were similar in both sampling programs. These plumes and their respective concentration ranges are as follows:

Plume	Concentration Ranges ($\mu\text{g/l}$)
South Plants - Basin A-A Neck Pathway Water Remedial Investigation Report Winter 1987/1988	0.540 - 11,100 0.570 - 460,000
Railyard Water Remedial Investigation Report Winter 1987/88	1.98 - 8.16 17.8 (one detection)
Central Pathways Water Remedial Investigation Report Winter 1987/88	2.94 - 53.3 2.02 - 68.8
Basin F - Basin F East Pathways Water Remedial Investigation Report Winter 1987/88	2.54 - 38,000 2.00 - 63,000
Northern Off-post Pathway Water Remedial Investigation Report Winter 1987/88	2.38 - 1370 2.42 - 1180

Water Remedial Investigation Report chloroform concentrations ranged from 0.540 $\mu\text{g/l}$ to 38,800 $\mu\text{g/l}$; winter 1987/88 sampling period concentrations were from 0.570 $\mu\text{g/l}$ to 460,000 $\mu\text{g/l}$. The highest Water Remedial Investigation Report concentrations were detected in the Basin F plume, whereas those for winter 1987/88 were detected in the Basin A plume. Well 36109, which had the highest concentration detected during winter 1987/88 event, was not sampled during the Water Remedial Investigation.

The general configurations of the South Plants - Basin A - A Neck plumes are similar for both sampling periods. However, as a result of the increased well density in the CMP sampling network, the winter 1987/88 plume shows more detail than is shown in the Water Remedial Investigation Report.

The Railyard plume is basically the same size and configuration for both sampling periods. The maximum chloroform concentration was 8.16 $\mu\text{g/l}$ during the Water Remedial Investigation Report, versus 17.8 $\mu\text{g/l}$ during winter 1987/88. Both values were in samples from Well 03523.

An isolated plume consisting of two detections above CRL occurs in the northeast portion of Section 3 and parts of Section 2. This plume is approximately the same for both sampling periods.

The Central Pathways plumes have similar configuration in both sampling periods. Changes that were observed on the winter 1987/88 map include the extension of the plume to the western edge of Section 27 and its shortened extension west of the RMA boundary.

The Basin F-Basin F East plume show no significant changes in configuration between the two sampling periods. The concentrations range from 2.00 to 63,000 $\mu\text{g/l}$ in winter 1987/88, and from 2.54 to >38,800 $\mu\text{g/l}$ for the Water Remedial Investigation Report. For both, the area of highest concentration is located just northeast of Basin F in Section 26. Well 26133 had a reported concentration of >38,800 $\mu\text{g/l}$ during the Water Remedial Investigation, compared to 63,000 $\mu\text{g/l}$ during winter 1987/88.

The Northern Off-post Plume exhibits the same general size, configuration and concentration ranges for both the Water Remedial Investigation Report and the winter 1987/88 periods. However, a concentration high noted in the Water Remedial Investigation Report in off-post Section 13 was absent during winter 1987/88.

It should be noted, however, that contaminant migration occurs slowly with subtle concentration changes. Therefore, definitive assessment of such changes is not possible over a short time period.

4.3.8.3.3 Winter 1987/88 and Initial Screening Program Comparison. - Comparisons are made between the Initial Screening Program winter 1985/86 chloroform data interpretations and the winter 1987/88 CMP chloroform data interpretations. These comparisons are made to evaluate temporal changes in the distribution of chloroform that may be indicative of migration occurring within the 2-year time period separating the Initial Screening Program and the CMP.

The two interpretations are generally similar in that the highest chloroform concentrations are located in the South Plants - Basin A area and downgradient of Basin F. Chloroform concentrations in the South Plants appear much higher in the CMP interpretation because of the use of a larger concentration value for the highest isoconcentration contour; actual data values are comparable between both programs.

In the RMA Western Tier, numerous scattered, isolated chloroform detections appear in the CMP interpretation that were not presented in the Initial Screening Program interpretation despite adequate well coverage. This may be indicative of chloroform migration in the Western Tier.

Greater CMP well coverage in Sections 27, 34 and 35 upgradient of the Northwest Boundary Containment System appears to account largely for the differences between CMP and Initial

Screening Program interpretations in this area. Widespread low-level chloroform contamination in the area shown in the CMP interpretation may originate in part from Sand Creek Lateral. The Initial Screening Program data interpretation in this same area indicates a source in central Section 27, with no apparent continuity with chloroform contamination further upgradient.

4.3.8.3.4 Confined Denver Formation. - Chloroform analyses were performed on 136 ground-water samples from the confined flow system during the winter 1987/88 monitoring program. Concentrations above the CRL ranging from 0.570 to 460,000 $\mu\text{g/l}$ were detected in 36 of the samples analyzed. The majority of the detections (21) were from zones A and 2, which had 15 and 6 detections, respectively. The area of highest concentration is located in Section 36, just down-gradient of the South Plants. The maximum depth at which chloroform was detected was 191 ft below ground level in Well 33032 at a concentration of 480 $\mu\text{g/l}$. The analytical results from these wells are summarized in Table 4.3-13, and point plot presentations of the data are shown in Figures A-65 through A-68.

4.3.8.3.5 Winter 1987/88 Water Remedial Investigation Report Comparison. - For the Water Remedial Investigation Report, chloroform concentrations above the CRL were detected in only 19 of 141 samples analyzed, ranging from 1.71 to 194 $\mu\text{g/l}$. Table 4.3-13 summarizes these results for each of the confined flow system zones. The area of highest concentration is located in the same general area as that identified for the winter 1987/88 sampling period. The majority of detections are in samples from zones A, 1 and 2. Well 36592, for which the highest concentration was detected during the winter 1987/88 event, was not sampled during the Water Remedial Investigation. The highest concentration value during the Water Remedial Investigation was detected in Well 02035, which had similar levels during the winter 1987/88 event. An anomalous change was noted in Well 26061, where the concentrations decreased from 29.5 $\mu\text{g/l}$ during the Water Remedial Investigation to only 0.680 $\mu\text{g/l}$ during the winter 1987/88 program. The reliability of these data and factors contributing to this change may relate to variations in analytical methodology or sampling method, as well as to natural variations in contaminant concentration.

4.3.8.4 Trichloroethylene. Analyses for trichloroethylene (TRCLE) were performed on 455 ground-water samples collected during the winter 1987/88 monitoring event. The CRLs for the various monitoring programs were 0.560 $\mu\text{g/l}$ for the TMP, 1.31 $\mu\text{g/l}$ for Task 25, and 1.31 $\mu\text{g/l}$ for Task 44. TRCLE concentrations above CRLs ranged from 0.615 to 2400 $\mu\text{g/l}$ in 146 of the samples analyzed. TRCLE was detected above CRLs in the confined flow system in 30 out of 137 samples from all zones except zone B. TRCLE detections above CRLs in both the unconfined and confined systems for the 1988 monitoring program are summarized in Table 4.3-14.

4.3.8.4.1 Unconfined Flow System. - TRCLE concentrations above CRLs were detected in 116 of 318 ground-water samples collected from unconfined aquifer wells during the winter 1987/88 event. Concentrations ranged from 0.619 $\mu\text{g/l}$ to 2400 $\mu\text{g/l}$. TRCLE plumes were observed in the South Plants-Basin A Pathway, the Basin A Neck Pathway, the Western Tier and Railyard Pathways, and the Basin F East, Basin F, and Northern Off-post Pathways (Figure 4.3-19).

The highest concentration of TRCLE (2400 $\mu\text{g/l}$) was detected in the plume in the South Plants-Basin A Pathway in extreme southwest Section 36 and northwest Section 1. From this area, the plume extends northwest into the Basin A Neck Pathway and to south-central Section 2.

TRCLE was also detected in the western portion of the Basin A Neck Pathway in Section 27 and north, both to the Northwest Boundary Containment System in Section 22 and to the off-post area southwest of the Northwest Boundary Containment System. Migration is primarily through saturated alluvium, except through portions of Sections 1 and 2, where flow occurs through saturated unconfined Denver Formation beneath unsaturated alluvium.

Along the Western Tier and Railyard Pathways in Sections 9, 4 and 33, TRCLE was detected in concentrations ranging from 0.630 to 125 $\mu\text{g/l}$.

Concentrations above CRLs ranged from 1.15 to 67.9 $\mu\text{g/l}$ in the plume that originates in Basin C and extends north along the Basin F East and Basin F Pathways.

A plume in the Northern Off-post Pathway extends about 7,500 ft off-post. The highest concentration downgradient of the North Boundary Containment System was detected in Well 37344 at a concentration of 7.71 $\mu\text{g/l}$.

The historical relationship between on- and off-post TRCLE contamination is indicated by the shaded area (Figure 4.3-19) west of RMA. The concentrations from the EPA wells that were sampled between December 1985 and March 1987 ranged from 5 to 100 $\mu\text{g/l}$.

4.3.8.4.2 Winter 1987/88 and Water Remedial Investigation Report Comparison. - TRCLE distribution in the unconfined flow system for the Water Remedial Investigation and the winter 1987/88 sampling event were compared using the plume maps shown in Figure 4.3-19 and in Figure 4.2-16 (Appendix F) of the Water Remedial Investigation Report. TRCLE concentrations above the CRL were detected in 100 of 332 samples analyzed for the Water Remedial Investigation and in 116 of 318 samples analyzed for the winter 1987/88 event.

Distributions of TRCLE were generally similar for both sampling programs. The plumes and the concentrations of TRCLE detected during the two periods are summarized as follows:

Plume	Concentration Ranges ($\mu\text{g/l}$)
South Plants-Basin A and Basin A Neck Pathways	
Water Remedial Investigation Report	1.43 - 2840
Winter 1987/88	0.620 - 2400
Western Tier and Railyard Pathways	
Water Remedial Investigation Report	<1.30 - 156
Winter 1987/88	0.630 - 125
Basin F East and Basin F Off-post Pathways	
Water Remedial Investigation Report	1.33 - 68.7
Winter 1987/88	1.15 - 67.0
Northern Off-post Pathway	
Water Remedial Investigation Report	1.59 - 7.06
Winter 1987/88	1.94 - 7.71

Although distributions and concentration ranges are similar, some differences were noted between the two sampling programs. Continuity of the plume of TRCLE contamination along the Basin A Neck Pathway in southern Section 26 as shown on the Water Remedial Investigation Report plume map could not be confirmed during the winter 1987/88 event because of changes in the monitoring network. Also, the extent of TRCLE contamination west of the Northwest Boundary Containment System was greater during winter 1987/88.

The Basin F plume shown for winter 1987/88 differs from the Water Remedial Investigation Report plume in the lateral distribution of TRCLE against the southern border of the North Boundary Containment System during the winter 1987/88 event. The common wells sampled during the Water Remedial Investigation had reported concentrations below the CRL.

4.3.8.4.3 Winter 1987/88 and Initial Screening Program Comparison. - For the purposes of assessing temporal changes in the rate and extent of TRCLE contamination, comparisons are made between the Initial Screening Program winter 1985/86 data interpretation (Initial Screening Report, Figure C-19) and the CMP winter 1987/88 data interpretation (Figure 4.3-19). The two interpretations are regionally very similar, but specific differences do exist.

In the South Plants area, TRCLE contamination continuous with the South Plants plume extends as far south as south-central Section 2 in the CMP interpretation. The interpretative differences

result largely from different well networks, as there is no Initial Screening Program TRCLE plume in Section 2.

Similarly, TRCLE contamination at both the North Boundary Containment System and the Northwest Boundary Containment System is much more pervasive in the CMP interpretation than in the Initial Screening Program. This results largely from monitoring-well network differences, though not in all cases. Adequate Initial Screening Program well coverage near the North Boundary Containment System did not yield TRCLE detections. This variability may be a result of monitoring program variation. In the RMA Western Tier, the Initial Screening Program and CMP interpretations are very similar. More dense CMP well coverage in Section 9 indicates off-post upgradient TRCLE sourcing. Initial Screening Program data were not adequate to make this interpretation.

4.3.8.4.4 Confined Flow System. - Analyses for TRCLE were performed on 137 ground-water samples collected from the confined flow system during the winter 1987/88 monitoring event. TRCLE concentrations above CRLs ranging from 0.615 to 440 $\mu\text{g/l}$ were detected in 30 of the samples analyzed. Detections were most frequent within zone A; however, TRCLE was detected above CRLs in all zones sampled, except zone B. The maximum concentration was detected in the South Plants area in south-central Section 36. The maximum depth of TRCLE above CRLs investigated during the winter 1987/88 sampling event was 191 ft below ground level, at a concentration of 2.77 in Well 33032 completed in zone 7. The distribution of TRCLE in the confined flow system could generally be correlated with the TRCLE distribution in the unconfined aquifer. The methods by which TRCLE is entering the confined units probably includes downward vertical migration through fractures, discontinuous confining layers, or improperly sealed or abandoned wells. Analytical results for the winter 1987/88 sampling event are summarized in Table 4.3-14. Selected concentration plots from the winter 1987/88 sampling event are presented in Figures A-69 through A-73.

4.3.8.4.5 Winter 1987/88 and Water Remedial Investigation Report Comparison. - Water Remedial Investigation Report analytical results indicated that TRCLE concentrations above CRLs were detected in 11 of 141 samples from wells completed in the confined flow system zones, with concentrations ranging from 1.24 to 8.68 $\mu\text{g/l}$. Analytical results are summarized in Table 4.3-14.

During the winter 1987/88 event, TRCLE was detected above CRLs in 11 wells that had no detectable concentrations during the Water Remedial Investigation. The greatest discrepancy was noted in analytical results for Well 23201, in which a concentration of 13.5 $\mu\text{g/l}$ of TRCLE was detected during the winter 1987/88 event but was reported as below the CRL in the Water

Remedial Investigation Report. Conversely, the Water Remedial Investigation Report reported a TRCLE concentration of 8.68 $\mu\text{g/l}$ for Well 37387, in which the detected concentration was below CRLs for the winter 1987/88 event. The maximum concentration of 440 $\mu\text{g/l}$ detected during the winter 1987/88 event in Well 36592 could not be compared with Water Remedial Investigation Report results because this well was not sampled in the Water Remedial Investigation.

4.3.8.5 Tetrachloroethylene. Tetrachloroethylene (TCLEE) was detected above the CRL in 106 of 455 wells analyzed during the winter 1987/88 sampling event with concentrations ranging from 0.829 to 1700 $\mu\text{g/l}$. CRLs for the various monitoring programs were 0.750 $\mu\text{g/l}$ for the TMP, 2.76 $\mu\text{g/l}$ for Task 25, and 1.30 $\mu\text{g/l}$ for Task 44. TCLEE was above the CRL in confined flow system zones VC, A, 1U, 1, 2, 5 and 7. TCLEE detections above CRLs in both the confined and unconfined systems for the 1988 monitoring program are presented in Table 4.3-15.

4.3.8.5.1 Unconfined Flow System. - Of the 318 ground-water samples collected from the unconfined flow system, 92 had detections above the CRL ranging from 0.879 to 1700 $\mu\text{g/l}$. The highest CRL for the three quarters (2.76 $\mu\text{g/l}$) was used as the lowest isoconcentration value in constructing the plume map shown in Figure 4.3-20.

TCLEE plumes were detected in the South Plants-Basin A, Basin A Neck, Basin F, Western Tier, and the First Creek and Northern Off-post Pathways.

The South Plants-Basin A - Basin A Neck plume originates in the South Plants area and continues north through Basin A and into the Basin A Neck. Some TCLEE flow to the south is also likely as a result of the ground-water mound in the South Plants. Plume concentrations range from 0.880 to 1700 $\mu\text{g/l}$ with the highest located in northwest Section 1. TCLEE is migrating primarily through zones of saturated alluvium, although migration through the unconfined Denver Formation is evident in Section 1.

The Basin F plume is detected at the northeastern boundary of Basin F and northeast along the Basin F Pathway to the North Boundary Containment System. Concentrations in the plume range from 0.910 to 870 $\mu\text{g/l}$ (Well 26133).

The off-post plume trends northward along the Northern Off-post and First Creek Off-post Pathways. Concentrations within this plume range from 6.32 to 112 $\mu\text{g/l}$ (Well 37344). Flow is primarily through saturated alluvium.

The Western Tier plume trends north-south, parallel to the RMA western border and is located entirely within Section 4. Concentrations reported in this area do not exceed 3.63 $\mu\text{g/l}$. Contaminant flow is entirely through saturated alluvium.

4.3.8.5.2 Winter 1987/88 and Water Remedial Investigation Report Comparison. - TCLEE distributions in the unconfined flow system for the Water Remedial Investigation Report and the winter 1987/88 sampling event were compared using Figure 4.3-20 of this report and Figure 4.2-17 (Appendix F) of the Water Remedial Investigation Report. TCLEE was present above CRLs in 70 of the 332 samples analyzed for the Water Remedial Investigation Report and in 92 of 318 samples analyzed for the winter 1987/88 event.

Both sampling programs show similar plumes. These are listed below with their respective concentration ranges:

Plume	Concentration Ranges ($\mu\text{g/l}$)
South Plants - Basin A Pathway	
Water Remedial Investigation Report	0.820 - 184
Winter 1987/88	0.880 - 1700
Basin F Pathway	
Water Remedial Investigation Report	2.83 - 926
Winter 1987/88	3.05 - 870
Northern Off-post Pathway	
Water Remedial Investigation Report	3.86 - 115
Winter 1987/88	6.32 - 112
Western Tier Pathway	
Water Remedial Investigation Report	2.01 - 4.76
Winter 1987/88	1.15 - 3.63

Water Remedial Investigation Report concentrations ranged from 0.820 to 926 $\mu\text{g/l}$ compared to 0.880 to 1700 $\mu\text{g/l}$ for the winter 1987/88 event. The highest concentrations were found in the Basin F plume while those for the winter 1987/88 period were detected in the Basin A-South Plants plume. The Water Remedial Investigation Report reported 926 $\mu\text{g/l}$ and winter 1987/88 reported 870 $\mu\text{g/l}$ for Well 26133.

The general size and shape of the Basin A-South Plants plume for both sampling periods is similar. The high concentration for the winter 1987/88 sampling event was 1700 $\mu\text{g/l}$ compared to 184 $\mu\text{g/l}$ in the Water Remedial Investigation Report. This difference is due to the fact that

Well 01517, where the high was detected in the winter 1987/88 event, was not sampled during the Water Remedial Investigation.

The Basin F, Northern Off-post, and Western Tier plumes show only minor variations in configuration or concentrations between the two sampling periods. The variations may be the result of either analytical or sampling variability.

4.3.8.5.3 Winter 1987/88 and Initial Screening Program Comparison. - Comparisons are made between the Initial Screening Program winter 1985/86 TCLEE results (Initial Screening Program Report, Figure C-21) and the CMP winter 1987/88 TCLEE results (Figure 4.3-20) for the purpose of assessing changes in the rate and extent of TCLEE migration. From a regional perspective, both interpretations are very similar. At a local scale, however, there are several differences.

The CMP interpretation presents a continuous plume throughout the South Plants - Basin A - Basin A Neck area. Two separate localized areas of high TCLEE concentrations are presented in the Initial Screening Program interpretation; one located in the northwest portion of Section 1 in the South Plants and the other in the northeast portion of Basin A. The differences between the CMP and Initial Screening Program data presentations in this area appear to be largely interpretative, as the well control of each program is comparable.

Two separate contoured TCLEE masses appear in the Initial Screening Program data interpretation in the Basin F - North Boundary Containment System area, whereas the CMP interpretation presents one continuous plume. Differences appear to be largely interpretative or attributable to well network changes in the Basin F-North Boundary Containment System area.

In the RMA Western Tier, the Initial Screening Program and CMP interpretations indicate low-level TCLEE contamination with a possible north-south orientation subparalleling hydraulic flow lines in the area. Both interpretations have small contoured masses in the area.

4.3.8.5.4 Confined Flow System. - TCLEE concentrations above CRLs were detected in 14 of 137 ground-water samples from the confined flow system. These detections, are generally associated with the alluvial plumes. The majority of concentrations above CRLs (6) were from zone A. Other above-CRL detections were from zones VC, 1U, 1, 2, 5 and 7. The area of highest concentration (65.0 $\mu\text{g/l}$) is located in Well 02543 in zone VC at a depth of 28 ft below ground level. Concentrations in samples from the confined flow system ranged from 0.829 to 65.0 $\mu\text{g/l}$. The deepest contamination by TCLEE is in Well 33032 at a depth of 191 ft below ground

level and a concentration of 1.98 $\mu\text{g/l}$ in zone 7. Point plot presentations of the data are shown in Figures A-74 and A-75.

4.3.8.5.5 Winter 1987/88 and Water Remedial Investigation Report Comparison. - Sampling of the Water Remedial Investigation Report network included 141 confined flow system wells, of which there were 3 with concentrations above the CRLs. These ranged from 1.54 to 5.70 $\mu\text{g/l}$ in samples from zones A, 1 and 2. Concentrations in these three samples were similar for both sampling events. Eight of the samples which had concentrations above CRLs in the winter 1987/88 event were below the CRL in the Water Remedial Investigation Report. Three wells sampled in the winter 1987/88 event were not analyzed in the Water Remedial Investigation Report. Well 02543, which had a concentration of 65.0 $\mu\text{g/l}$ during winter 1987/88, was one of the wells not sampled in the Water Remedial Investigation Report.

4.3.9 Dibromochloropropane (DBCP)

During the winter 1987/88 monitoring event, 426 ground-water samples were analyzed for DBCP. The CRLs for the winter 1987/88 sampling event were 0.130 $\mu\text{g/l}$ for Tasks 44 and 25, and 0.190 $\mu\text{g/l}$ for the TMP. DBCP concentrations ranging from 0.144 $\mu\text{g/l}$ to 57,000 $\mu\text{g/l}$ were detected in 67 of the samples analyzed. DBCP was only reported in 5 confined flow system samples from zones A, 2 and 3. DBCP detections above CRLs in both the unconfined and confined systems for the 1988 monitoring program are summarized in Table 4.3-16.

4.3.9.1 Unconfined Flow System. A total of 307 ground-water samples from unconfined wells were analyzed for DBCP. Of these, 62 contained concentrations above CRLs ranging from 0.144 $\mu\text{g/l}$ to 57,000 $\mu\text{g/l}$. The highest CRL for the three quarters analyzed (0.190 $\mu\text{g/l}$) was used as the lowest isoconcentration value in constructing the contaminant distribution map shown in Figure 4.3-21.

Four DBCP plume areas were identified: the South Plants - Basin A - Basin A Neck Pathway, the Basin F Pathway, the Northern Off-post Pathway, and in the Railyard Pathway.

The largest DBCP plume trends north from a concentration high in the South Plants area to Basin A and then northwest along the Basin A Neck Pathway to the Northwest Boundary Containment System. In Sections 35, 26 and 27, the plume is interpreted to be confined to the Basin A Neck paleochannel. As indicated in Figure 4.3-21, the continuity of this portion of the plume was inferred based on historical data. The plume also extends southeast into central Section 1 and a short distance west into northeastern Section 2. The plume migrates away from

the concentration high in the South Plants area, in the area of a ground-water mound from which ground water flows radially. DBCP concentrations within the plume range from 0.140 to 57,000 $\mu\text{g/l}$. The maximum reported DBCP concentration was in Well 01517 located in northwest Section 1. The main source of this plume is probably the South Plants with smaller subsequent contributions from Basin A.

The second plume of DBCP shown in Figure 4.3-21 extends northeast from the Basin F area, along the Basin F Pathway, to the North Boundary Containment System. DBCP concentrations within this plume range from 0.150 to 53.0 $\mu\text{g/l}$, with the highest concentration reported in Well 26133 located northeast of Basin F.

A third plume extends north of the boundary along the Northern Off-post Pathway into Sections 11, 12 and 13. This plume shows strong indications of discontinuity from the operation of the North Boundary Containment System. The highest concentration detected was 13.3 $\mu\text{g/l}$ in Well 37344 located in the southwest corner of Section 12.

The fourth plume extends from southwestern Section 3 along the Railyard Pathway to the Irondale Containment System. DBCP concentrations within the plume range from 0.270 to 54.0 $\mu\text{g/l}$, with the highest concentration recorded in Well 03523 located in southwestern Section 3.

4.3.9.1.1 Winter 1987/88 and Water Remedial Investigation Report Comparison. - DBCP distributions in the unconfined flow system for the Water Remedial Investigation Report and the winter 1987/88 sampling event were compared using Figure 4.3-21 of this report and Figure 4.2-18 (Appendix F) of the Water Remedial Investigation Report. DBCP was detected above CRLs in 63 of 299 samples collected in the Water Remedial Investigation Report and in 62 of 307 samples analyzed for the winter 1987/88 event.

DBCP is present in similar locations in both sampling programs. The four DBCP plumes and their respective concentration ranges are as follows:

Plume	Concentration Ranges ($\mu\text{g/l}$)
South Plants - Basin A - Basin A Neck Pathway	
Water Remedial Investigation Report	0.146 - 278
Winter 1987/88	0.140 - 57,000
Basin F Pathway	
Water Remedial Investigation Report	0.720 - 35.4
Winter 1987/88	0.150 - 53.0
Northern Off-post Pathway	
Water Remedial Investigation Report	0.400 - 10.6
Winter 1987/88	0.180 - 13.3
Railyard Pathway	
Water Remedial Investigation Report	0.416 - 45.4
Winter 1987/88	0.270 - 54.0

DBCP concentrations above CRLs ranged from 0.146 to 278 $\mu\text{g/l}$ in the Water Remedial Investigation Report and 0.144 to 57,000 $\mu\text{g/l}$ for the winter 1987/88 sampling event. The highest DBCP concentrations were identified in the South Plants - Basin A - Basin A Neck Pathway for both the Water Remedial Investigation Report and the winter 1987/88 sampling network. However, Well 36001, which had the highest concentration (278 $\mu\text{g/l}$) in the Water Remedial Investigation Report, had an inconsistent value of 1.65 $\mu\text{g/l}$ in the winter 1987/88 event. Well 01517, which had the highest DBCP concentration in the winter 1987/88 event (57,000 $\mu\text{g/l}$), was not sampled during the Water Remedial Investigation. Therefore, the areas of highest concentrations remained the same during both sampling events with a large discrepancy in concentrations for Well 36001.

The South Plants - Basin A - A Neck plumes are very similar for both sampling periods. However, due to the increase in the sampling network, the South Plants portion of the winter 1987/88 plume appears to be more detailed than the Water Remedial Investigation Report plume. The maximum concentration within this plume varied from 278 $\mu\text{g/l}$ in the Water Remedial Investigation Report to 57,000 $\mu\text{g/l}$ in the winter 1987/88 event, with the differences noted above.

The Basin F plume showed no significant changes in configuration or concentration between sampling periods. The area of highest concentration for both networks is located northeast of Basin F in Section 26.

The Northern Off-post plume did not show significant changes between the Water Remedial Investigation Report and winter 1987/88 sampling event.

4.3.9.1.2 Winter 1987/88 and Initial Screening Program Comparison. - For the purposes of assessing temporal changes in the rate and extent of DBCP migration, comparisons were made between the winter 1985/86 Initial Screening Program data interpretation (Initial Screening Program Report, Figure 3.2-22) and the winter 1987/88 CMP data interpretation (Figure 4.3-21). Regionally, the interpretations are very similar with numerous, localized exceptions.

In the CMP interpretation, a much higher plume concentration and plume continuity from South Plants through Basin A and Basin A Neck appears to relate directly to the comprehensive CMP well network. Disparate concentrations in several wells in the area common to both the CMP and Initial Screening Program programs may indicate DBCP migration.

In the Basin F - North Boundary Containment System area, the CMP interpretation has a long, continuous plume traversing the area in contrast to the Initial Screening Program interpretation of two separate DBCP areas; one is near Basin F, the other at the North Boundary Containment System. The differences may not be attributable to network differences alone, as the CMP concentrations are higher and encompass a greater area. The differences between the Initial Screening Program and CMP interpretations may be attributed, at least in part, to contaminant migration and monitoring network.

In the RMA Western Tier, the DBCP contamination connecting the Railyard with the Irondale Containment System is one continuous plume in the CMP interpretation, whereas it is composed of separate, contoured masses with several isolated detections in the Initial Screening Program interpretation. Analytical results from both periods are similar, but the CMP concentrations are slightly elevated compared to those presented in the Initial Screening Program.

4.3.9.1.3 Winter 1987/88 and Spring and Summer 1988 Comparison. - During the spring 1988 sampling period, 21 of 216 wells had DBCP detections above the CRL within the range 0.221 to 93.0 $\mu\text{g/l}$. Newly installed Well 36181 (93.0 $\mu\text{g/l}$) was not sampled during the winter 1987/88 sampling period. However, Well 36181 was installed to replace Well 36001 (they are 40 ft apart). Well 01517 (57,000 $\mu\text{g/l}$ during winter 1987/88) was not sampled during spring 1988.

The shape and concentrations of the Western Tier and Basin F plume are very similar (Figures 4.3-21 and 4.3-22). The Basin A plume is confined to Basin A during spring 1988, and does not extend through the Basin A Neck Pathway to the Northwest Boundary Containment System as in winter 1987/88 due to a change in the well networks.

During the summer 1988 sampling period, 6 of 22 wells had DBCP detections above the CRL within the range of 0.235 to 37.0 $\mu\text{g/l}$. Data from this sampling period are shown on Table 4.3-17.

4.3.9.2 Confined Flow System. DBCP analyses were performed on 119 ground-water samples from the confined flow system during the winter 1987/88 monitoring program. DBCP concentrations above CRLs ranged from 0.202 to 21.0 $\mu\text{g/l}$ in 5 of the samples analyzed. These detections were from zones A, 2 and 3, which had 2, 2 and 1 detections, respectively. Winter 1987/88 sampling event analytical results are summarized in Table 4.3-16. Point plots from the winter 1987/88 and spring 1988 analytical results are presented in Figures A-76 through A-82. The deepest contamination of confined flow system ground water occurs in zone 2 at 134 ft below ground level. This is in Well 24171 at a concentration of 0.234 $\mu\text{g/l}$. The lowest stratigraphic unit containing DBCP was zone 3, in which Well 24168 had a reported concentration of 0.200 $\mu\text{g/l}$.

4.3.9.2.1 Winter 1987/88 and Water Remedial Investigation Report Comparison. - DBCP above CRL was detected in 5 of 141 Water Remedial Investigation Report samples analyzed with concentrations ranging from 0.191 to 0.779 $\mu\text{g/l}$. These were recorded in samples collected from zones A, 2 and 4. DBCP was detected in zone A (Well 01036) during both the Water Remedial Investigation Report and the Winter 1987/88 event. Well 36592, which had the maximum concentration during the winter 1987/88 sampling event, was not sampled during the Water Remedial Investigation Report. The highest DBCP detection in the Water Remedial Investigation Report, of 0.779 $\mu\text{g/l}$, was observed within zone 2 (Well 37387), but was below the CRL during the winter 1987/88 event.

4.3.9.2.2 Winter 1987/88 and Spring and Summer 1988 Comparison. - During the spring 1988 sampling period, 5 of 89 wells had DBCP detections above CRL ranging from 0.304 to 250 $\mu\text{g/l}$. DBCP detections were only found in zones A, 1U, 1 and 2. The highest concentration was reported in zone A (250 $\mu\text{g/l}$ in Well 36182). Well 36182 was not sampled during winter 1987/88. The highest concentration during winter 1987/88 was also found in zone A (21.0 $\mu\text{g/l}$ in Well 36592), but the well was not sampled during spring 1988. The deepest contamination of DBCP was found at 155 ft below ground level in Well 36171, completed in zone 1, with a concentration of 0.30 $\mu\text{g/l}$. The lowest stratigraphic unit containing DBCP was zone 2, in which Well 26069 had a reported concentration of 0.364 $\mu\text{g/l}$.

During the summer 1988 sampling period, no DBCP detections above the CRL were reported in the 15 wells sampled. Data for the quarterly specific area monitoring is listed in Table 4.3-17.

4.3.10 Dicyclopentadiene (DCPD)

DCPD analyses were performed on 404 ground-water samples obtained during the winter 1987/88 monitoring event. The CRLs for samples collected under the contributing tasks were 5.00 $\mu\text{g/l}$ for the TMP, and 9.31 $\mu\text{g/l}$ for both Tasks 25 and 44. DCPD concentrations ranging from 10.6 $\mu\text{g/l}$ to 12,000 $\mu\text{g/l}$ were reported in 63 of the samples analyzed. DCPD was detected above CRLs in the confined flow system in 5 samples only, from zones VC, 2 and 5. DCPD detections above CRLs in both the unconfined and confined systems for the FY88 monitoring program are summarized in Table 4.3-18.

4.3.10.1 Unconfined Flow System. A total of 280 ground-water samples from wells completed in the unconfined flow system were analyzed for DCPD during the winter 1987/88 sampling event. Concentrations of DCPD ranging from 10.6 to 12,000 $\mu\text{g/l}$ were reported in 58 of the 280 samples analyzed. The highest CRL (9.31 $\mu\text{g/l}$) was used as the lowest isoconcentration value in constructing the plume map shown in Figure 4.3-23.

DCPD contamination in the unconfined flow system is located in three main areas: the South Plants -Basin A - Basin A Neck Pathway, along the Basin F Pathway, and in the First Creek Off-post Pathway. Isolated DCPD detections above the CRL are present on-post in Sections 3, 4, 9, 24 and 33. The highest isolated detection was 53.60 $\mu\text{g/l}$ in Well 04038. Geraghty and Miller (1986) reported spills of DCPD in Section 36 and the South Plants Tank Farm, and leakage from the chemical sewer lines.

The DCPD plume located in the South Plants area is interpreted to extend north through Basin A and along the Basin A Neck into Section 35. The highest concentration reported in the winter 1987/88 event (12,000 $\mu\text{g/l}$) is located in west-central Section 1. A subsidiary plume is interpreted in northeast Section 2. Contaminant flow in Sections 1 and 2 is primarily through the unconfined flow system while flow through the Basin A and A-Neck is through saturated alluvium.

DCPD in the Basin F Pathway extends from the Basin F area to the North Boundary Containment System. Concentrations within this plume reach a maximum of 2100 $\mu\text{g/l}$ in Well 23049 in south-central Section 23.

Downgradient of the North Boundary Containment System, a plume extends along the First Creek Off-post Pathway into Section 14. In the First Creek Off-post Pathway, concentrations range from a high of 529 $\mu\text{g/l}$ to a low of 11.9 $\mu\text{g/l}$. Contaminant flow in this plume is primarily within

saturated alluvium. Isolated DCPD detections above CRL in Sections 3, 4, 33 and 9 were reported in the winter 1987/88 monitoring event results.

4.3.10.1.1 Winter 1987/88 and Water Remedial Investigation Report Comparison. - DCPD distributions in the unconfined flow system for the Water Remedial Investigation and winter 1987/88 sampling events were compared using Figure 4.3.-23 of this report and Figure 4.2-19 of the Water Remedial Investigation Report. Within the unconfined flow system, DCPD was detected above CRLs in 31 of 297 samples analyzed in the Water Remedial Investigation, compared to 58 of 280 samples analyzed for the winter 1987/88 sampling event.

The extent of DCPD contamination along the Basin F Pathway was similar for both programs. The plume within South Plants - Basin A - A Neck is quite different. The concentration ranges for the two main areas of DCPD contamination for both sampling programs are as follows:

<u>Plume</u>	<u>Concentration Ranges ($\mu\text{g/l}$)</u>
South Plants - Basin A - Basin A Neck Pathway	
Water Remedial Investigation Report	58.6 (single detection)
Winter 1987/88	18.9 - 12,000
Basin F - First Creek Off-post Pathway	
Water Remedial Investigation Report	10.7 - 1200
Winter 1987/88	11.9 - 2100

The geometry of the DCPD plume extending from the South Plants through Basin A and the Basin A Neck was assessed during the Third Quarter FY87 Water Remedial Investigation. The Water Remedial Investigation Report inferred the existence of a plume in southwestern Section 36 based on historical data and mapped a separate plume in the Basin A Neck based on a single detection of 58.6 $\mu\text{g/l}$. During the winter 1987/88 event, several wells in Sections 1 and 2 were added to the sampling network. As a result, DCPD contamination as high as 12,000 $\mu\text{g/l}$ was identified in the South Plants area. None of the wells in Section 1 and 2 where DCPD was detected above CRLs during the winter 1987/88 event were sampled in the Water Remedial Investigation.

The extent of DCPD contamination along the Basin F and First Creek Off-post Pathways was very similar in the two sampling events. Concentrations ranged from 11.9 $\mu\text{g/l}$ to 2100 $\mu\text{g/l}$ during winter 1987/88 and from 10.7 $\mu\text{g/l}$ to 1200 $\mu\text{g/l}$ for the Water Remedial Investigation. The highest concentration detected above CRLs was in Well 23049 in both events. Within this plume, reported concentrations of DCPD generally doubled during the winter 1987/88 event.

4.3.10.1.2 Winter 1987/88 and Initial Screening Program Comparison. - Comparisons between the winter 1985/86 Initial Screening Program DCPD results (Initial Screening Program Report, Figure 3.2-26) and the winter 1987/88 DCPD results (Figure 4.3-23) are discussed here for the purposes of assessing temporal changes in the rate and extent of DCPD migration. There are large differences between the two interpretations, as the Initial Screening Program reported only 7 detections, and only 3 of these were contoured as continuous. In contrast, the CMP interpretation based on above-CRL detections presents continuous plumes in the South Plants - Basin A - Basin A Neck area and in the Basin F - North Boundary Containment System area. Due to these significant differences in detections, very little information can be obtained from comparing the CMP and Initial Screening Program interpretations.

A second source of information regarding distribution of DCPD is presented in a report prepared by Spaine, et al., (1984) and reproduced in the Initial Screening Program as Figure 3.2-29. The plume configurations from the Spaine report are very similar to the CMP interpretation despite the 3-year period separating them.

In the South Plants - Basin A area, both interpretations are very similar. Both indicate localized DCPD concentration highs in the South Plants tank farm and in eastern Section 2. Two other localized highs in South Plants and in Basin A proper as depicted in the Spaine interpretation are not present in the CMP interpretation.

A significant difference between the Spaine, et al., (1984) interpretation and that presented in the CMP appears in the areas north, west and northwest of Basin F. The Spaine report clearly depicts DCPD contamination in these areas at concentrations greater than 50 $\mu\text{g/l}$. No such detections in these areas are indicated by CMP data, and this difference may be indicative of DCPD migration through the area.

Downgradient of Basin F in easternmost Section 23, the Spaine data interpretation indicates DCPD at detected concentrations 3 to 5 times higher than those recorded later in the CMP. CMP well coverage is very good in eastern Section 23. The differences in reported concentrations may partly be the result of DCPD migration to the North Boundary Containment System.

It should be noted that the comparisons made between the CMP and Spaine interpretations are limited by several constraints. The sampling, quality analysis and quality control, analytical standards, and protocol used in the CMP and previous Remedial Investigation/Feasibility Study tasks were not employed to the same extent in the Spaine effort. The Spaine interpretation did not

indicate which wells were used to generate the contoured data. Comparisons involving the Spaine data are thus somewhat tenuous.

4.3.10.2 Confined Flow System. DCPD analyses were performed on 124 ground-water samples from the confined flow system during the winter 1987/88 monitoring program. Concentrations above CRL ranging from 12.3 $\mu\text{g/l}$ to 330 $\mu\text{g/l}$ were detected in 5 of the samples analyzed. winter 1987/88 sampling event analytical results are summarized in Table 4.3-18. Point plots from the winter 1987/88 analytical results are presented in Figures A-83 through A-85.

The highest DCPD concentration reported was from a sample obtained from Well 25013 (zone 2), located east of the North Plants in Section 25. Contamination in this well does not appear related to any reported DCPD contamination in the unconfined flow system. Historically, this well has not had any reported detections above the CRL and therefore is suspect to either sampling or analytical variability. The deepest detection of DCPD was reported at 90 ft below ground level in Well 22024, completed in zone 5, at a concentration of 21.3 $\mu\text{g/l}$.

4.3.10.2.1 Winter 1987/88 and Water Remedial Investigation Report Comparison. - Five of 124 samples analyzed reported DCPD concentrations above the CRL from confined flow system zones in the winter 1987/88 event. Previously, no detectable concentrations were reported from the 139 samples analyzed in the Water Remedial Investigation. Well 25013 reported a concentration of 330 $\mu\text{g/l}$ in the winter 1987/88 event, but was reported as less than the CRL in the Water Remedial Investigation program.

4.3.11 Diisopropylmethyl phosphonate (DIMP)

Diisopropylmethyl phosphonate (DIMP) concentrations ranging from 11.5 $\mu\text{g/l}$ to 9000 $\mu\text{g/l}$ were detected in 136 of 431 samples analyzed during winter 1987/88 monitoring. The CRLs for samples collected under various tasks were 18.5 $\mu\text{g/l}$ for the TMP, 10.1 $\mu\text{g/l}$ for Task 25, and 10.5 $\mu\text{g/l}$ for Task 44. DIMP was detected in the confined flow system in 11 samples from zones A, 1U, 1, 2, 3 and 4. DIMP detections in both the unconfined and confined systems for the FY88 monitoring program are summarized in Table 4.3-19.

4.3.11.1 Unconfined Flow System. Ground-water samples from 306 wells completed in the unconfined flow system were analyzed for DIMP during the winter 1987/88 event. Concentrations of DIMP ranging from 11.5 $\mu\text{g/l}$ to 9000 $\mu\text{g/l}$ were measured in 125 of these samples. The highest CRL (18.5 $\mu\text{g/l}$) was used as the lowest isoconcentration value in constructing the contaminant plume map shown in Figure 4.3-24.

DIMP occurs in a continuous plume extending along the Basin A-Basin A Neck Pathway and the Basin F East - Basin F Pathway. North of the North Boundary Containment System, a DIMP plume is observed in the First Creek and Northern Off-post Pathways. Smaller plumes exist along the North Plants Pathway and in a north-south trending area beginning in Section 27 and extending north as far as the Northwest Boundary Containment System.

The highest DIMP concentration measured during the winter 1987/88 event was 9000 $\mu\text{g/l}$ in the Basin A area at Well 36084. From Basin A, DIMP in excess of 1000 $\mu\text{g/l}$ is interpreted to extend through the Basin A Neck and north all the way to the North Boundary Containment System. The three wells sampled in Basin A Neck, Wells 35065, 36139 and 36142, have reported concentrations of 1400, 170 and 9000 $\mu\text{g/l}$, respectively. Within Section 26, DIMP occurs primarily in the unconfined flow system. DIMP concentrations exceed 5000 $\mu\text{g/l}$ in southeast Section 23. In western Section 23, DIMP concentrations were reported in excess of 1000 $\mu\text{g/l}$. This has been interpreted to extend westward in the vicinity of the Basin F Northwest Pathway (Figure 4.3-24). Where data were not available to provide detail regarding the likely plume geometry, historical data were used to supplement winter 1987/88 data. Examples of this are in the inferred plume geometries in the southern part of the Basin A Neck Pathway and the First Creek and Northern Off-post Pathways.

A plume of DIMP is shown originating in north-central Section 25 and migrating along the North Plants Pathway toward the North Boundary Containment System. The maximum concentration reported within the plume was 562 $\mu\text{g/l}$. The plume merges with the Basin F plume in west-central Section 24.

DIMP occurs south of the Northwest Boundary Containment System at concentrations as high as 54.8 $\mu\text{g/l}$. The source of this contamination is unknown, but may be related to migration along the Basin A Neck Pathway.

North of the North Boundary Containment System, DIMP flow is interpreted to extend along the Northern and First Creek Off-post Pathways. Off-post DIMP concentrations were reported at a maximum of 5390 $\mu\text{g/l}$ along the First Creek Off-post Pathway in central Section 14. DIMP was detected off-post to within 2,000 ft southeast of the South Platte River. No additional monitoring wells are present that are in the flow path of this plume and nearer to the river. The lateral downgradient extent of this plume is not known.

4.3.11.1.1 Winter 1987/88 and Water Remedial Investigation Report Comparison. DIMP distributions in the unconfined flow system for the Water Remedial Investigation Report and the winter 1987/88 events were compared using Figure 4.3-24 of this report and Figure 4.2-20 (Appendix F) of the Water Remedial Investigation Report. Within the unconfined flow system, DIMP was detected in 121 of 294 samples analyzed for the Water Remedial Investigation Report, compared to 125 of 306 samples analyzed for the winter 1987/88 sampling event.

The occurrence of DIMP was similar for both sampling programs. The concentration ranges for the two main areas of DIMP contamination between sampling programs are as follows:

<u>Plume</u>	<u>Concentration Ranges ($\mu\text{g/l}$)</u>
Basin A - Basin F Pathways	
Water Remedial Investigation Report	11.9 - 12,100
Winter 1987/88	11.5 - 9000
First Creek - Northern Off-post Pathways	
Water Remedial Investigation Report	13.1 - 2170
Winter 1987/88	11.6 - 5390

In the Basin A-Basin F Pathway plume, Well 36084 contained the highest DIMP concentration for each program. The First Creek-Northern Off-post Pathway plume had two different wells with high DIMP concentrations reported for the Water Remedial Investigation and winter 1987/88. Well 37313 had 2170 $\mu\text{g/l}$ DIMP during the Water Remedial Investigation Report and 3850 $\mu\text{g/l}$ during winter 1987/88. Well 37396 had 5390 $\mu\text{g/l}$ DIMP reported in winter 1987/88 and was not sampled during the Water Remedial Investigation Report. These wells contained the highest DIMP concentrations reported for the Water Remedial Investigation and winter 1987/88 sampling periods, respectively.

The differences observed between sampling programs may generally be attributed to the change from 10.5 $\mu\text{g/l}$ to 18.5 $\mu\text{g/l}$ as the lowest isoconcentration value and changes in the sampling network. Some notable differences include:

1. The Water Remedial Investigation Report interpreted DIMP to extend along the Basin A Neck Pathway to near the Northwest Boundary Containment System. During the winter 1987/88 event, the lowest isoconcentration value was higher and therefore the plume was not extended.

2. The extent of DIMP contamination in excess of 1000 $\mu\text{g/l}$ along the First Creek Off-post Pathway is greater during winter 1987/88 due to the inclusion of additional wells to the sampling network.
3. An area of DIMP with concentrations in excess of 5000 $\mu\text{g/l}$ was inferred at Basin F during the Water Remedial Investigation but was absent in the winter 1987/88 data presentation.
4. The off-post extensions of the DIMP plumes are shorter during winter 1987/88. This is due to the higher value used for the low contour during the Water Remedial Investigation.

4.3.11.1.2 Winter 1987/88 and Initial Screening Program Comparison. For the purposes of assessing temporal data variability that may be attributable to DIMP migration, comparisons were made between the Initial Screening Program winter 1985/86 DIMP results (Initial Screening Program Report, Figure 3.2-30) and the winter 1987/88 CMP interpretation (Figure 4.3-24). The two data interpretations are so similar that little variability in contaminant distribution can be observed by comparing them. One minor difference occurs in northern Section 25, where the CMP interpretation indicates a small DIMP plume downgradient of the North Plants. The lack of Initial Screening Program wells in this area accounts for the absence of reported DIMP in this area during the Initial Screening Program.

A more useful comparative information source on the quantitative distribution of DIMP was presented in Spaine, et al. (1984) and reproduced as Figure 3.2-33 in the Task 4 Initial Screening Program Report. The Spaine interpretation indicates DIMP was detected further upgradient (southern edge of Section 36) than is indicated by the CMP data interpretation. Similarly, much higher DIMP concentrations in the Spaine map are shown in the Basin A Neck-Basin C area than were detected in the CMP. The Spaine interpretation also indicates there was plume continuity from Basin A Neck to the Northwest Boundary Containment System; this isn't firmly established in the CMP interpretation.

The Spaine interpretation also clearly indicates a DIMP plume traversing a large portion of Section 25 (North Plants). This plume is similar to the CMP data interpretation (Figure 4.3-24) although the CMP DIMP plume is considerably smaller. The important factor complicating comparisons of the Spaine, et al. (1984) interpretations with the CMP data interpretations is that no well control is presented in the Spaine information. Differences in sampling, quality analysis and quality control and analytical methods further complicate these comparisons. However, the most salient

feature of the Spaine-CMP comparison is that DIMP contamination appears to have been more areally extensive on-post and at higher concentrations than was recorded in the CMP data. Data variability observed between the two programs may partly be the result of DIMP migration.

4.3.11.1.3 Winter 1987/88 and Spring and Summer 1988 Comparison. During the spring 1988 program, DIMP was detected in 66 of 204 samples collected in concentrations ranging from 19.8 $\mu\text{g/l}$ to 32,000 $\mu\text{g/l}$. The highest value was recorded in the northwest corner of Basin A (Figure 4.3-25). DIMP distribution is generally similar in extent to the winter 1987/88 plume map; however, some changes are apparent. Due to the inclusion of wells in the vicinity of the North Plants during the spring 1988 sampling event, a small plume of DIMP was identified in east-central Section 25.

Table 4.3-20 summarizes the detections of DIMP based on the summer 1988 sampling event. During this event, DIMP was detected in 16 of 19 samples at concentrations ranging from 50.5 $\mu\text{g/l}$ to 990 $\mu\text{g/l}$. In addition, the concentration of DIMP in 8 wells sampled during the summer 1988 event was reported as $>400 \mu\text{g/l}$. This method of reporting DIMP did not provide sufficient information to assess locations of concentration highs.

4.3.11.2 Confined Flow System. DIMP analyses were performed on 125 ground-water samples from the confined flow system during the winter 1987/88 monitoring program. Concentrations ranging from 11.5 to 5900 $\mu\text{g/l}$ were detected in 11 of the samples analyzed from zones A, 1U, 1, 2, 3 and 4. Analytical results for the confined flow system from the winter 1987/88, spring 1988, and summer 1988 programs are summarized in Table 4.3-19. Selected point plots from the sampling programs cited above are presented in Figures A-86 through A-92.

DIMP detections in the confined flow system occurred primarily beneath Basin C and the Basin A Neck in zones 1U and 1. Detections were also recorded beneath Basins A and F. The two highest values recorded for the winter 1987/88 event were beneath the Basin A Neck in zone 1U. The deepest Denver Formation contamination by DIMP is in zone 2, Well 26129. The concentration is 1800 $\mu\text{g/l}$ and the depth is 113 ft below ground level. The deepest stratigraphic occurrence of DIMP is in zone 4, in Well 37365, which has a reported concentration of 11.5 $\mu\text{g/l}$ at a depth of 55 ft below ground level.

4.3.11.2.1 Winter 1987/88 and Water Remedial Investigation Report Comparison. - In the Water Remedial Investigation, DIMP was detected in 11 of 136 samples from the confined flow system. Concentrations ranged from 17.0 $\mu\text{g/l}$ to 5350 $\mu\text{g/l}$.

Confined Denver Formation DIMP detections were very similar between the Water Remedial Investigation and the winter 1987/88 events. Eight of the 11 detections recorded during the Water Remedial Investigation were repeated with similar concentrations during the winter 1987/88 event. The remaining 3 detections were from wells not sampled during both programs. The largest variation in DIMP concentration between programs was at Well 26129, where DIMP levels increased from 214 $\mu\text{g/l}$ to 1800 $\mu\text{g/l}$ between the Water Remedial Investigation and the winter 1987/88 event. This increase may have been a result of changes in contaminant plume geometry or analytical error.

4.3.11.2.2 Winter 1987/88 and Spring and Summer 1988 Comparison. - DIMP was detected in 4 of 82 samples analyzed from confined flow system units during the spring 1988 sampling event. In this program DIMP concentrations ranged from 19.8 to 2500 $\mu\text{g/l}$. DIMP contamination during the spring 1988 event is similar to the winter 1987/88 results. Wells 35066, 35016 and 37365 yielded similar concentrations of DIMP during both programs. The fourth detection was from a well not sampled during the winter 1987/88 event. The deepest DIMP detection was found at 78 ft in Well 26090, completed in Denver zone 3, with a concentration of 99.1 $\mu\text{g/l}$. The lowest stratigraphic unit containing DIMP is zone 4, in Well 37365, which has a reported concentration of 19.8 $\mu\text{g/l}$ at a depth of 55 ft below ground level.

During the summer 1988 sampling event, DIMP was detected in 2 of 13 samples analyzed from confined flow system units (Table 4.3-19). These detections, measured at Wells 26086 and 26129, nearly duplicate values obtained during the winter 1987/88 event. Data for the quarterly specific area monitoring is listed in Table 4.3-20.

4.3.12 Arsenic

Arsenic analyses were performed on 439 ground-water samples collected during the winter 1987/88 monitoring event. The CRL for the TMP and Task 25 was 2.50 $\mu\text{g/l}$ and was 2.50 and 3.07 $\mu\text{g/l}$ for Task 44. Concentrations ranging from 2.61 to greater than (>) 50.0 $\mu\text{g/l}$ were detected in 93 of the samples analyzed. Concentrations reported as >50.0 were provided by the laboratory under CMP contract guidelines. These values, because they provide limited data regarding concentration highs, are of limited utility. Unconfined alluvial aquifer and confined flow system arsenic detections for the FY88 monitoring program are summarized in Table 4.3-21.

4.3.12.1 Unconfined Flow System. A total of 313 ground-water samples collected from unconfined monitoring wells were analyzed for arsenic. Of these, 80 detections were reported at concentrations that ranged from 2.61 to >50.0 $\mu\text{g/l}$. Although arsenic may be found naturally,

there has been no value recognized by RMA investigators or regulators as representative of background levels of arsenic in ground water at RMA. Therefore, a plume is defined here by concentrations of arsenic in excess of 3.07 $\mu\text{g/l}$ (Figure 4.3-26).

In considering background levels of arsenic in RMA ground water, it is worthy of note that arsenic detections, even very close to the CRL, were largely limited to known RMA source areas. This indicates that background levels of arsenic are probably very low in the RMA area.

Arsenic forms a plume that originates in the South Plants and in Basin A and extends northwest as a wide plume encompassing the Basin A Neck Pathway, the Basin F West, Northwest Pathways, and the Basin F Pathway. The westward termination of this large plume is at the Northwest Boundary Containment System. The northward termination of this plume is at the North Boundary Containment System. Smaller plumes occur northwest and north of the Northwest Boundary Containment System and North Boundary Containment System.

The highest concentrations of arsenic occur in the South Plants-Basin A-Basin A Neck Pathway and northeast of Basin F in Section 26. These concentrations are all listed as $>50.0 \mu\text{g/l}$. There is an apparent lack of continuity in these high concentrations that suggests several sources of arsenic contribute to this plume. In the off-post area a plume occurs north of the North Boundary Containment System in the First Creek Off-post Pathway. This plume comprises 3 wells and concentrations range from 3.39 to 4.30 $\mu\text{g/l}$. The overall arsenic plume configuration is primarily located in areas of saturated alluvium except in Section 26.

4.3.12.1.1 Winter 1987/88 and Water Remedial Investigation Report Comparison. - Arsenic was detected in 74 out of 291 Water Remedial Investigation Report samples compared to 80 out of 313 for the winter 1987/88 sampling event. Concentrations ranging from 2.56 to 315 $\mu\text{g/l}$ were reported in the Water Remedial Investigation Report. The areal extent of arsenic contamination as shown in Figures 4.2-21 (Appendix F) of the Water Remedial Investigation Report is very similar to that for the winter 1987/88 sampling network. The plumes for each period have been interpreted somewhat differently. For the Water Remedial Investigation Report, arsenic occurrence on-post is shown as two separate plumes, one in the Basin A - Basin A Neck Pathway and one in the Basin F - Basin F West - Northwest Pathway. Current data indicate arsenic is more likely to occur as one continuous plume. This was indicated by new data collected north of Basin A Neck.

In addition to the differences cited above, it should be recognized that it is not possible to assess changes in the highest concentration reported. This is due to a lack of quantification of high concentrations during winter 1987/88.

4.3.12.1.2 Winter 1987/88 and Initial Screening Program Comparison. - Comparisons were made between the Initial Screening Program Task 4 winter 1985/86 arsenic data interpretation (Initial Screening Program Report, Figure 3.2-34) and the winter 1987/88 CMP arsenic data interpretation (Figure 4.3-26) for the purposes of assessing the changes in the rate and extent of arsenic migration.

The two interpretations are similar in that areas of highest arsenic concentrations occur in Basin A and downgradient of Basin F. Differences between the two interpretations are largely attributable to sparse Initial Screening Program well control and the resultant lack of detections in areas where the CMP indicates arsenic contamination (i.e., at the North Boundary). Because differences in interpretations may reasonably be attributable to well network changes, an assessment of changes in contaminant distribution resulting from arsenic migration is not possible at this time.

4.3.12.2 Confined Denver Formation. During the winter 1987/88 sampling event, arsenic analyses were performed on 126 wells completed in the confined flow system. Concentrations ranging from 3.23 $\mu\text{g/l}$ to >50.0 $\mu\text{g/l}$ were detected in 13 samples analyzed from wells in the zones A, IU, 1, 2, 3 and 5 (Figures A-93 through A-95). The maximum depth of arsenic reported was in Well 03003, zone 3, at a depth of 148 ft below ground level and a concentration of 3.88 $\mu\text{g/l}$. The highest concentration was detected in a sample collected from Well 36140 at a depth of 23 ft below ground level in zone A beneath Basin A. The lowest stratigraphic unit containing arsenic was zone 5 in Well 27055 with a contamination of 3.23 $\mu\text{g/l}$. Table 4.3-21 summarizes the confined flow system analytical data for all sampling events.

4.3.12.2.1 Winter 1987/88 and Water Remedial Investigation Report Comparison. - The sampling network decreased from 139 wells in the Water Remedial Investigation to 126 wells in the winter 1987/88 sampling period. Of these, there were 15 detections during the Water Remedial Investigation Report and 13 during the winter 1987/88 event above the CRL. Concentrations detected during the Water Remedial Investigation ranged from 2.57 to 22.2 $\mu\text{g/l}$, compared to a high value of >50.0 $\mu\text{g/l}$ for the winter 1987/88 sampling event. Table 4.3-21 summarizes these results for each of the confined flow system zones. Other differences between the two sampling periods include a detection in the zone VC during the Water Remedial Investigation, compared to none during the winter 1987/88 event. Other concentration detection differences, however, suggest other influences. An example is the change from no detections in zone 4 during the winter 1987/88 event to detectable concentrations of 4.98 $\mu\text{g/l}$ and 8.08 $\mu\text{g/l}$ during the Water Remedial Investigation Report program in wells (22023 and 24175) common to each program.

4.3.13 Fluoride

Analyses for fluoride were performed on 431 ground-water samples obtained during the winter 1987/88 monitoring event. The CRLs for the various monitoring programs (in $\mu\text{g/l}$) were 1220 and 1000 for Task 44, and 1000 for Task 25 and TMP. Fluoride concentrations ranging from 1230 to 190,000 $\mu\text{g/l}$ were reported in 349 of the 431 samples analyzed. Unconfined and confined flow system fluoride detections above 1220 $\mu\text{g/l}$ for the FY88 monitoring program are summarized in Table 4.3.-22.

Fluoride is a naturally occurring constituent of ground water. The water quality south and east of the major source areas has been monitored for fluoride to establish a background quality. However, background levels for fluoride have not been defined for the RMA area. For the purposes of this report, based largely upon the highest CRL value for fluoride in FY88 monitoring, fluoride plumes have been defined here as those areas where concentrations are in excess of 1220 $\mu\text{g/l}$.

4.3.13.1 Unconfined Flow System. Fluoride was analyzed in 302 samples from unconfined wells during the winter 1987/88 sampling event. Concentrations above CRL ranged from 1230 $\mu\text{g/l}$ to 21,000 $\mu\text{g/l}$ in 245 samples. Fluoride data for samples collected from wells upgradient of the study area show fluoride concentrations in these areas range from 570 to 1000 $\mu\text{g/l}$ (Table 4.3-23).

The highest CRL value (1220 $\mu\text{g/l}$) was used in constructing the contaminant distribution map shown in Figure 4.3-27. As will be illustrated below, the use of 1200 $\mu\text{g/l}$ as a background value for fluoride results in widespread distribution of fluoride plume areas. Because the distribution is greater than that indicated by other RMA contaminants, it is likely that a higher concentration should be used to represent RMA contributions of fluoride to ground water. For this discussion, fluoride concentration is considered high if it is in excess of 5000 $\mu\text{g/l}$. High fluoride concentrations (in excess of 5000 $\mu\text{g/l}$) are mapped in three areas: the South Plants, the Basin A Neck Pathway, and the Basin F Pathway.

In the South Plants area, high fluoride levels occur in a relatively small area which extends from northwestern Section 1 into southwest Section 36. The highest fluoride concentration detected in this plume during the winter 1987/88 sampling event was 21,000 $\mu\text{g/l}$. Fluoride concentrations between 1,230 and 5,000 $\mu\text{g/l}$ are reported in a large plume surrounding the South Plants, which includes most of Sections 1, 2, 35 and 36. This distribution indicates that fluoride is probably migrating radially away from sources within South Plants. A smaller plume with a maximum

concentration at 2,210 $\mu\text{g/l}$ is located along the Central South Pathway. This may be related to fluoride contamination originating from South Plants or from Sand Creek Lateral.

Occurrences of fluoride in the Basin A Neck Pathway range in concentrations from 5,200 to 12,000 $\mu\text{g/l}$. Fluoride concentrations between 2,000 and 5,000 $\mu\text{g/l}$ extend in a widening plume from the Basin A Neck north to Basin F and west to the Northwest Boundary Containment System.

In the vicinity of the RMA boundary northwest of the Northwest Boundary Containment System, the concentrations are generally below 2,000 $\mu\text{g/l}$.

The third area of fluoride contamination in excess of 5,000 $\mu\text{g/l}$ identified during winter 1987/88 monitoring extends from northeast of the Basin F area along the Basin F Pathway toward the North Boundary Containment System. The highest fluoride concentration in this plume was 15,000 $\mu\text{g/l}$, northeast of Basin F in Section 23. The plume is interpreted to branch into northwest oriented and northeast oriented components around a subtle bedrock high in central Section 23. In the northeastern component, fluoride flow is through unsaturated alluvium and fluoride concentrations drop below 5000 $\mu\text{g/l}$ south of the North Boundary Containment System. Along the northwest component, fluoride flow is possibly through the unconfined flow system, extending off-post, bypassing the west end of the North Boundary Containment System. At the RMA boundary, concentrations decrease to less than 5000 $\mu\text{g/l}$.

North of the North Boundary Containment System, fluoride concentrations greater than 2000 $\mu\text{g/l}$ were detected in wells along the First Creek Off-post Pathway and the Northern Off-post Pathway. The highest concentration (4,420 $\mu\text{g/l}$) was detected in the First Creek Off-post Pathway in central Section 14.

Fluoride ranging in concentration from 1,230 to 3,490 $\mu\text{g/l}$ is present in the Western Tier Pathway, in the area of the southwestern RMA boundary.

Outside defined RMA pathways, greater than 2,000 $\mu\text{g/l}$ fluoride concentrations were reported in eastern Sections 24 and 25 and western Sections 19 and 30. Because of limited well control, the eastern and southern extent of these elevated concentrations was not determined.

4.3.13.1.1 Winter 1987/88 and Water Remedial Investigation Report Comparison. - The distribution of fluoride in the unconfined ground-water flow system is similar to historic fluoride distribution as outlined in the Water Remedial Investigation Report (Figure 4.2-22, Appendix F).

Fluoride distribution within the South Plants area is comparable between winter 1987/88 and the Water Remedial Investigation Report although fluoride was reported in 11 wells in Sections 36 and 2 for winter 1987/88 event, as opposed to 5 wells for the Water Remedial Investigation. The reported fluoride concentrations were comparable for the wells sampled in both programs.

Within Basin A, fluoride contamination was not well defined on the winter 1987/88 plume map because a limited number of wells were sampled. The Water Remedial Investigation Report map, which used a different set of wells, shows fluoride concentrations in excess of 5,000 $\mu\text{g/l}$ in this same area. As shown on Figure 4.3-27, the 5,000 $\mu\text{g/l}$ contour lines in Basin A have been inferred from Water Remedial Investigation data because winter 1987/88 data were not available. Concentrations of fluoride within the same well located in the Basin A Neck Pathway increased from 4,020 $\mu\text{g/l}$ in the Water Remedial Investigation Report to 12,000 $\mu\text{g/l}$ in the winter 1987/88 sampling event (Well 35065).

The general distributions and concentrations of fluoride within the Basin F plume are similar in the Water Remedial Investigation and winter 1987/88. The Western Tier plume was not present on the Water Remedial Investigation Report distribution map, but was contoured for the winter 1987/88 event. Of the four wells making up the Western Tier plume that were sampled in both programs, only one well had a reported detection above the CRL during the Water Remedial Investigation.

4.3.13.1.2 Winter 1987/88 and Initial Screening Program Comparison. - For the purposes of assessing temporal changes in the rate and extent of fluoride contamination, comparisons were made between the Initial Screening Program winter 1985/86 results (ISP Report Figure 3.2-37) and the CMP winter 1987/88 fluoride results (Figure 4.3-27). Both interpretations depict fluoride contamination as being widespread and diffuse. In both interpretations, areas of highest fluoride concentrations are located in the South Plants-Basin A, Basin A Neck and downgradient of Basin F.

A noteworthy difference appears in the Initial Screening Program interpretation west of Basin F. Here, elevated fluoride detections (greater than 3,000 $\mu\text{g/l}$) are not shown in the CMP interpretation despite the fact that the wells in the area are common to both programs. The differences in this area west of Basin F may be attributable to fluoride migration and/or monitoring program variability.

CMP fluoride plumes in the Western Tier and in Section 34 (Figure 4.3-27) are not presented in the older Initial Screening Program interpretation largely because of a lack of Initial Screening Program wells.

4.3.13.1.3 Winter 1987/88 and Spring and Summer 1988 Comparison. - Data for the spring and summer 1988 sampling rounds are summarized in Table 4.3-22. Fluoride analyses were performed on 216 ground-water samples from wells screened within the unconfined aquifer during the spring 1988 sampling round. Fluoride concentrations above 1,220 $\mu\text{g/l}$ ranged from 1,230 to 300,000 $\mu\text{g/l}$ in 165 of the samples analyzed. The distribution map shown in Figure 4.3-28 reflects a continuous plume of fluoride greater than 5,000 $\mu\text{g/l}$ originating at South Plants and extending through the Basin A-A Neck and the Basin F Pathways to the North Boundary Containment System. There is an off-post plume with concentrations greater than 5,000 $\mu\text{g/l}$ north of the western part of the North Boundary Containment System and extends approximately 2,000 ft to the northwest along the First Creek Off-post Pathway.

Fluoride concentrations in excess of 10,000 $\mu\text{g/l}$ are present in Basin A and along the Basin F Pathway. The maximum fluoride concentrations reported from the spring 1988 analytical results were 302,000 and 330,000 $\mu\text{g/l}$ from samples obtained in Wells 26041 and 33068, respectively. Because the contamination in Well 33068 lies outside the known fluoride contaminant plumes, this level is highly suspect.

In comparison to the winter 1987/88 plume, the general distribution and the area of highest concentration are similar for spring 1988 quarter. There are significant differences, however, in the interpreted extent of contamination within the 1,220 and 5,000 $\mu\text{g/l}$ contours. For example, a small plume of fluoride in excess of 2,000 $\mu\text{g/l}$ occurs in southeast Section 25, yet is absent on the winter 1987/88 map. This results from the inclusion of wells in the North Plants vicinity for the spring 1988 sampling event. In addition, the isolated fluoride detection of 330,000 $\mu\text{g/l}$ was from Well 33068, which was not sampled in the winter 1987/88 sampling event. Other differences noted for spring 1988 but not winter 1987/88 include a small plume emanating from the Railyard; a larger plume in the Western Tier, a plume near the confluence of First Creek and O'Brian Canal, the absence of a concentration high in the South Plants, and a higher concentration maximum reported on the northeast side of Basin F. Most of the variations in plumes are probably due to a change in the sampling network, but the number of changes shows the importance of using a sufficiently detailed monitoring network to assess the character of contaminant occurrence and migration patterns at RMA.

During the summer 1988 monitoring event, fluoride concentrations above 1,220 $\mu\text{g/l}$ were reported in all 26 of the samples analyzed from the unconfined flow system in the Basin F area. Concentrations ranged from 1,600 $\mu\text{g/l}$ to 180,000 $\mu\text{g/l}$ and the data are listed in Table 4.3-24.

Fluoride concentrations in excess of 5,000 $\mu\text{g/l}$ originate in the Basin F area and are observed in wells in the Basin F West, North and Northwest Pathways. The highest fluoride concentration measured during the summer 1988 event was 180,000 $\mu\text{g/l}$, compared to 300,000 $\mu\text{g/l}$ in the same well during the spring 1988 sampling event (Well 26041). This well, which was sampled in the winter 1987/88 sampling event, was not analyzed for fluoride.

4.3.13.2 Confined Flow System. Fluoride analyses were performed on 129 ground-water samples from the confined flow system during the winter 1987/88 monitoring event. Concentrations above 1,220 $\mu\text{g/l}$ were recorded in 104 wells from zones VC and A through 7, with values ranging from 1,280 $\mu\text{g/l}$ to 190,000 $\mu\text{g/l}$. Analytical results for the confined flow system from the winter 1987/88, spring 1988, and summer 1988 programs are summarized in Table 4.3-22. Selected point plots from the sampling programs cited above are presented in Figures A-96 through A-108.

The maximum fluoride concentration of 190,000 $\mu\text{g/l}$ was reported in Well 26067, located in zone 2 beneath Basin C. This well, completed at 112 ft below ground level thus represents the highest concentration of fluoride in the confined flow system. Based on previous data and subsequent FY88 CMP work, this value is of questionable reliability. The deepest well in which fluoride was reported at a concentration above 1,220 $\mu\text{g/l}$ was Well 33032 at a concentration of 2,080 $\mu\text{g/l}$. The well depth was 191 ft below ground level and the well is completed in zone 7.

Fluoride concentrations greater than 3,000 $\mu\text{g/l}$ within confined flow system units are generally located in the vicinity of fluoride contamination within the unconfined flow system. In general, the highest fluoride concentrations in the confined flow system are located beneath Basin A, Basin A Neck, South Plants, and Basin C. Some reported fluoride concentrations in the confined flow system exceed those in all units stratigraphically above the zone they monitor. An example is Well 02030 in zone A (16,000 $\mu\text{g/l}$).

4.3.13.2.1 Winter 1987/88 and Water Remedial Investigation Report Comparison. - During the Water Remedial Investigation, fluoride concentrations above Water Remedial Investigation CRLs were measured in 80 of 139 samples. Concentrations ranged from 913 $\mu\text{g/l}$ to 7,870 $\mu\text{g/l}$. Table 4.3-22 summarizes these results for each zone. In general, fluoride contamination within confined flow system zones was similar in extent and magnitude between wells sampled during each program. One significant difference, however, exists at Well 26067. A fluoride concentration

of 190,000 $\mu\text{g/l}$ was recorded during winter 1987/88, while $<1,220 \mu\text{g/l}$ was reported for the same well in the Water Remedial Investigation Report. Historically (Initial Screening Program), this well was also below 1220 $\mu\text{g/l}$ for fluoride. Historical data thus indicate that this value may be erroneous, resulting from sampling, recording or laboratory errors. If validated, further investigation of mechanisms controlling contaminant migration in this area will be required.

4.3.13.2.2 Winter 1987/88 and Spring and Summer 1988 Comparison. - Fluoride concentrations in excess of 1,220 $\mu\text{g/l}$ were measured in 82 of 89 samples from confined flow system units during the spring 1988 sampling event. Table 4.3-22 summarizes these results. In this program, fluoride detections ranged from 1230 $\mu\text{g/l}$ to 12,000 $\mu\text{g/l}$. For wells sampled during both the spring 1988 and winter 1987/88 events, fluoride concentrations were generally similar. There were two exceptions. In Well 26067, 1780 $\mu\text{g/l}$ of fluoride was measured during the spring 1988, while 190,000 $\mu\text{g/l}$ were measured during winter 1987/88. It is suggested that the anomaly probably lies with the winter 1987/88 data, since the Water Remedial Investigation Report reported $<1,220 \mu\text{g/l}$ of fluoride in this same well. The highest fluoride level recorded during spring 1988 was 12,000 $\mu\text{g/l}$ at Well 35066. During winter 1987/88 event, only 3,410 $\mu\text{g/l}$ of fluoride was measured here. The deepest detection of fluoride during spring 1988 was at 187 ft below ground level in Well 33032, completed in zone 7 at a concentration of 1,650 $\mu\text{g/l}$.

During the summer 1988 sampling event, fluoride in excess of 1,220 $\mu\text{g/l}$ was measured in all 20 samples analyzed from confined flow system zones. Fluoride concentrations ranged from 1420 $\mu\text{g/l}$ to 7,600 $\mu\text{g/l}$. For wells sampled during both the summer 1988 and the winter 1987/88 events, fluoride concentrations were generally similar, with the exception of Well 26067 which has been discussed previously. Table 4.3-24 lists the data for the quarterly-specific area monitoring.

4.3.14 Chloride

Analyses for chloride were performed on 442 ground-water samples from wells screened within water-bearing units in the unconfined aquifer and the confined flow system during the winter 1987/88 monitoring event. Chloride concentrations ranging from 77,200 to 360,000 $\mu\text{g/l}$ were detected. Chloride detections in both the unconfined and confined systems for the FY88 monitoring program are summarized in Table 4.3-25.

Table 4.3-23 lists values for inorganic parameters for an off-post, downgradient well (37363) as compared to several unconfined upgradient wells. For the purpose of this report, this well was used to represent typical background chloride concentrations. The upgradient chloride range is

from 34,000 to 60,000 $\mu\text{g/l}$. Based on the range of average chloride concentrations from upgradient uncontaminated areas at RMA, a value of 75,000 $\mu\text{g/l}$ was chosen for the purposes of this report to represent the uppermost chloride values typical of uncontaminated areas at RMA. The lowest contour value of 75,000 $\mu\text{g/l}$ for chloride was used to construct the unconfined flow system plume map, Figure 4.3-29. This background was used because chloride concentrations from the CMP well network indicated that a value this low was needed to ensure that all potentially anomalous occurrences were considered in plume contouring.

4.3.14.1 Unconfined Flow System. A total of 311 ground-water samples from unconfined wells were analyzed for chloride. Of these, 231 reported concentrations above background for chloride (75,000 $\mu\text{g/l}$). Concentrations ranged from 77,300 $\mu\text{g/l}$ in Well 27001 to 7,400,000 $\mu\text{g/l}$ in Well 36100.

The highest concentrations resulting in the largest plumes of chloride were detected in the South Plants - Basin A - Basin A Neck Pathway, and northeast of Basin F. Smaller plumes on-post occur in the Western Tier, Section 3, from the South Plants northwest through the Central South Pathway, and throughout the sections near the North Boundary Containment System and the Northwest Boundary Containment System. Chloride plumes extend off-post north and west almost to the South Platte River.

The largest plume area shown in Figure 4.3-29 extends from west-central Section 1 through South Plants - Basin A, through the Basin A Neck Pathway and Basin F, to the Northwest Boundary Containment System, and the North Boundary Containment System and out to the South Platte River along the three major off-post pathways. The South Plants - Basin A portion of this plume extends north and south from a concentration high of 5,800,000 $\mu\text{g/l}$ in Well 01525 located in the northwest corner of Section 1. Another concentration high occurs in the Basin A Neck Pathway. The plume in this area extends northwest and southeast from the highest chloride concentration noted for the unconfined system in the winter 1987/88 event, 7,400,000 $\mu\text{g/l}$ in Well 36100. The plume extends from the eastern side of Section 36 and southwestern Section 31 towards Basin A. The chloride flow occurs primarily in the saturated alluvium except in portions of Section 1, 2 and 35 where chloride flow occurs in the unconfined saturated Denver Formation, beneath unsaturated alluvium.

From the Basin A Neck Pathway, the chloride plume increases in width and trends northwest and north from the Basin F Pathway. Except for isolated areas in the First Creek Off-post Pathway, chloride concentrations greater than 500,000 $\mu\text{g/l}$ are restricted to areas west and north of Basin F. Chloride concentrations greater than 1,000,000 occur in the Basin F Pathway and extend from the

Basin F area to within 400 ft of the North Boundary Containment System. The average plume width is 750 ft.

The well network for the winter 1987/88 sampling event provided increased coverage of the off-post areas north and northwest of RMA. An extensive chloride plume extends downgradient of the Northwest Boundary Containment System and North Boundary Containment System. The maximum width is approximately 3½ mi and extends from the Northwestern Off-post Pathway to the Northern Off-post Pathway. The chloride plume narrows to 5,000 ft in off-post Sections 10 and 3, where chloride concentrations occur at near background levels.

Two much smaller plumes occur along the Central South Pathway and the Western Tier Pathway. The chloride plume within the Central South Pathway extends approximately 13,000 ft along a northwest trend from central Section 2 to the southwestern portion of Section 27. The range of concentrations above background are from 85,000 µg/l (Well 02037) to 590,000 µg/l (Well 35052). Chloride flow occurs primarily through saturated alluvium except in Sections 1, 2, 22, 23, and 26 where migration also occurs through the unconfined flow system.

The chloride plume that exists in the Western Tier Pathway extends from the southern boundary of Section 9, north to the southwest corner of Section 33. Chloride concentrations in this plume range from 82,000 µg/l (Well 09011) to 170,000 µg/l (Well 04042).

Numerous isolated detections occur on RMA and in off-post areas but the concentrations are generally near the CRL of 75,000 µg/l used in this report.

4.3.14.1.1 Winter 1987/88 and Water Remedial Investigation Report Comparison. - The distributions of chloride in the unconfined flow system for the Water Remedial Investigation Report and the winter 1987/88 sampling event were compared using the plume maps shown in Figure 4.3-29 of this report and Figure 4.2-29 (Appendix F) of the Water Remedial Investigation Report. The concentration value used for the lowest contour on the Water Remedial Investigation Report chloride distribution map was 150,000 µg/l, as compared to 75,000 µg/l used for the winter 1987/88 chloride distribution map. Chloride occurred above background in 294 out of 294 samples analyzed in the Water Remedial Investigation Report and in 231 of 311 samples analyzed for winter 1987/88. The apparent disparity between the number of detections in the Water Remedial Investigation Report versus the winter 1987/88 event is explained by the different reporting levels chosen for chloride. The Water Remedial Investigation Report used the chloride concentration of 4,800 µg/l as the concentration for statistical purposes and a concentration value of 150,000 µg/l for purposes of constructing the plume map. In the CMP program, the chloride concentration of

75,000 $\mu\text{g/l}$ was chosen as an average background value for naturally occurring chloride levels in upgradient RMA ground water. This value was used as the lowest isoconcentration value for the chloride plume map.

Occurrences of chloride were similar for both sampling periods. These plumes and their respective concentration ranges for the Water Remedial Investigation Report and winter 1987/88 sampling networks are as follows:

<u>Plume</u>	<u>Concentration Ranges ($\mu\text{g/l}$)</u>
Basin A - South Plants - Basin A Neck Pathway	
Water Remedial Investigation Report	155,000 - 2,820,000
Winter 1987/1988	22,000 - 7,400,000
Central Pathway	
Water Remedial Investigation Report	151,000 - 750,000
Winter 1987/1988	7,300 - 470,000
Basin F Pathway	
Water Remedial Investigation Report	155,000 - 2,820,000
Winter 1987/1988	79,600 - 5,360,000
First Creek Off-post - Northern Off-post Pathways	
Water Remedial Investigation Report	<150,000 - 2,020,000
Winter 1987/88	68,800 - 1,130,000
Western Tier Pathway	
Water Remedial Investigation Report	153,000 - 185,000
Winter 1987/88	82,000 - 170,000

Due to the different background values used between the Water Remedial Investigation Report and the winter 1987/88 sampling periods, the low values summarized above are not comparable. The highest concentration noted for chloride in the Water Remedial Investigation Report was 2,820,000 $\mu\text{g/l}$ detected in sample from Well 26041. The highest chloride concentration detected from the winter 1987/88 sampling event was 7,400,000 $\mu\text{g/l}$ in Basin A Well 36100. Well 26041 was sampled in winter 1987/88, but the laboratory results were reported as >10,000 $\mu\text{g/l}$. This well has been sampled in three previous RI/FS sampling periods and the chloride concentrations were comparable to the Water Remedial Investigation result (2,820,000 $\mu\text{g/l}$). If the value used in the winter 1987/88 plume map was closer to 2,820,000 $\mu\text{g/l}$, the plume configuration shown in Figure 4.3.14-1 would be altered.

4.3.14.1.2 Winter 1987/88 and Initial Screening Program Comparison. - For the purposes of assessing temporal chloride data variability that may be attributable to migration, comparisons were

made between the Initial Screening Program winter 1985/86 chloride data interpretation (ISP Report Figure 3.2-41) and the winter 1987/88 CMP interpretation in Figure 4.3-29. Both interpretations are similar; different isoconcentration contour values and well networks account for the majority of interpretative differences. Interpretative differences between the Initial Screening Program and CMP programs in the South Plants - Basin A - A Neck area appear to be a function of using different networks.

CMP plumes in the RMA Western Tier and in Sections 2, 35 and 34 are not presented in the older Initial Screening Program interpretation because many of the detected concentrations in these plumes fall below the lowest isoconcentration value used to contour the Initial Screening Program data. The Initial Screening Program interpretation has considerably more area (with less well control) enclosed within a 100,000 $\mu\text{g/l}$ isoconcentration contour than the CMP interpretation. Differences between the two programs are strongly influenced by different isoconcentration values used to contour the analytical results and interpretive differences. Owing to the widespread diffuse nature of chloride contamination, it would be impracticable to attribute any of the observed Initial Screening Program/CMP differences to possible contaminant migration.

4.3.14.2 Confined Flow System. Chloride analyses were performed on 131 ground water samples from the confined flow system during the winter 1987/88 monitoring program. Chloride concentrations ranging from 79,000 $\mu\text{g/l}$ to 360,000 $\mu\text{g/l}$ occurred in 38 of the samples analyzed from zones VC and A through 5.

The area of highest chloride occurrences is located in Section 23, immediately upgradient of the North Boundary Containment System. Winter 1987/88 sampling event analytical results are summarized in Table 4.3-25. Point plots from the winter 1987/88 analytical results are presented in Figures A-109 through A-115. The deepest occurrence of chloride above 75,000 $\mu\text{g/l}$ was in Well 02031 in zone 1U at a depth of 141 ft below ground level. The concentration was 83,000 $\mu\text{g/l}$. The lowest stratigraphic occurrence was in zone 5, with many wells having concentrations above 75,000 $\mu\text{g/l}$.

4.3.14.2.1 Winter 1987/88 and Water Remedial Investigation Report Comparison. - For the Water Remedial Investigation Report monitoring program, chloride was analyzed in 139 samples, with 122 samples having chloride occurrences at concentrations greater than 4,800 $\mu\text{g/l}$. Table 4.3-25 summarizes these results for each.

The highest concentration of chloride detected during the Water Remedial Investigation Report was in Well 02030 at 7,290,000 $\mu\text{g/l}$. This well is located adjacent to a chlorine processing building

in the South Plants complex. The winter 1987/88 results from Well 02030 were reported as greater than 10,000 $\mu\text{g/l}$. Well 02030 is screened in zone A and is probably interacting with the unconfined flow system. Chloride occurrences within the shallower zones are generally located beneath unconfined plume areas.

4.3.15 Other Inorganic Parameters and Trace Metals

The ground water element of CMP was designed to collect data for general water quality parameters, major ions and trace metals. The purposes of this effort was to establish baseline water quality conditions, to support interpretations of the shallow hydrogeologic flow system, and to assess water quality impacts.

4.3.15.1 Baseline Water Quality. The basic quality of ground water that is flowing onto RMA through the unconfined flow system and the confined flow system aquifers has been assessed by examination of water quality data for wells upgradient of RMA source areas. Table 4.3-23 contains this information for several upgradient, on-post wells (12001, 11001 and 08002) and for one well located 0.5 mi southeast of RMA. The table also contains water-quality information from a single downgradient well (37363) collected from four sampling events. Table 4.3-26 contains typical background water chemistry from the confined flow system.

Although limited data are available, water is interpreted to be calcium/sodium chloride/sulfate in nature, with essentially equivalent molar ratios of sodium and calcium and of chloride to sulfate. These limited chemical data also infer that significant concentrations of bicarbonate plus carbonate (alkalinity) are present. Data presented in Table 4.3-23 show dramatic differences in upgradient versus downgradient water quality.

4.3.15.2 On-post Water Quality. Table 4.3-27 contains a summary of inorganic water quality data collected during the winter 1987/88 sampling event. On-post ground water is sodium chloride/sulfate in nature, exhibiting significantly higher total dissolved solids (or conductivity) than upgradient water quality reported in Table 4.3-23. Unlike upgradient water quality, on-post ground water has substantially higher concentrations of sodium, shifting the cation ratio to be more sodium-dominant.

Concentrations of both chloride and sulfate are substantially higher than concentrations observed in upgradient monitoring wells. Ratios of chloride to sulfate in on-post ground water are considerably higher than the same ratio in upgradient samples.

Basic water quality data in the unconfined flow system and confined flow system (Table 4.3-27) indicate that water in the confined flow system contains lower concentrations of all major dissolved ions. Although maximum values of the major ions in the unconfined system may exceed maximum values in the Denver Formation, mean concentrations are higher in the unconfined flow system.

4.3.15.3 Trace Metals. Ground water concentrations of several trace metals can also be found in Table 4.3-27. In general, concentrations are highly variable both within the unconfined flow system and confined flow system, with variations up to a factor of 10 for select metals. In general, concentrations observed in the unconfined flow system are similar to those observed in the confined flow system, with infrequent detections in excess of EPA Maximum Concentration Limits (MCLs).

4.4 Gas Chromatography/Mass Spectrometry (GC/MS) Results

To provide confirmation of analytical results for RMA target organic compounds as determined by gas chromatographic (GC) methods, analysis of CMP ground waters was also performed by gas chromatography/mass spectrometry (GC/MS) techniques. In addition to confirmation of target compound identity and concentration GC/MS analyses also provide identification and quantification for Tentatively Identified Compounds (TIC), commonly referred to as non-target compounds.

Samples from 57 on-post wells collected during the TMP were subjected to analysis by GC/MS techniques. Data for TICs from previous ground water monitoring programs (Task 4 and 44) were used in combination with results from the TMP to examine the need for modification of the list of target analyses. Recommendations for the addition of TICs to the target analyte list are based on the observed distribution and frequency of detection of specific TICs.

The GC/MS analytical methods used for the TMP sampling event were methods similar to EPA Methods 624 and 625 (USATHAMA Methods J8 and JJ8). Target analytes and CRLs for these methods are presented in Table 4.4-1. The table also presents CRLs for both GC and GC/MS methods. The greatest disparity in CRLs between the two is found in the semi-volatile analyses of pesticides to the use of more sensitive detectors for GC analyses. In all cases, dilution factors have been considered when evaluating the reported detection thresholds and sample results.

Appendix B contains the analytical results for ground-water analyses performed by GC/MS under the TMP. The comprehensive monitoring program (CMP) did not include GC/MS analyses during

the spring 1988 round of sampling. Results for Tasks 4 and 44 are available in Appendix D of the Water Remedial Investigation Report.

4.4.1 Confirmation of Volatile Organic Analyte Results

GC/MS methods were used to confirm the identity of target analytes identified by GC methods. Historically, concentrations have been considered confirmed if the GC and GC/MS values are within an order of magnitude for each other. For samples analyzed by GC and GC/MS, 210 sets of analyte identifications were reported. Of the 210 positive contaminant detections, 110 were confirmed within the order of magnitude guidelines. Fifty-three volatile organic analytes were not confirmed because concentrations were below the CRL for the confirmatory analyses. Forty-seven analytes were not confirmed within historical guidelines even though the concentration of the analyte was reported above the CRL for the confirmatory analysis. Volatile organic results are within the 90 percent confidence interval for all GC reported results as confirmed by the use of GC/MS analyses.

4.4.2 Confirmation of Semi-volatile Organic Analyte Results

One hundred and eighty-five sets of analyses for semi-volatiles were reported for the TMP. The criteria for semi-volatile organics is the same as that used in the volatile confirmation (i.e., plus or minus one order of magnitude). Thirty-five of these data sets were positively confirmed in accordance with this criteria. Eighty-three detections were not confirmed because sample results were below the confirmatory analysis CRLs. Four analytes did not meet the specified criteria because non-linear response values were reported outside the reporting limits. Sixty-three analytes were not confirmed within historical guidelines even though reported concentrations were above the confirmatory CRL value. The low percentage of positively confirmed analytes (20 percent) can be attributed to detection limits that are two orders of magnitude greater for GC/MS results than for GC techniques.

Review of the confirmatory data for the TMP indicates that confirmation for volatile organics using GC/MS is more feasible than for semi-volatile organics. Discrepancies are generally related to the different CRLs for GC and GC/MS methods. Volatile organics show better confirmation results because samples are generally prepared in a similar manner for both GC and GC/MS analyses. Semi-volatiles, however, follow different solvent extraction paths, and sensitivity is significantly decreased using GC/MS detectors versus semi-volatile GC detectors.

4.4.3 Nontarget Compound Analytical Results

TIC data have been compiled from Task 4, Task 44, and the TMP sampling events. Compounds identified with a reasonable degree of certainty or with a characteristic spectral pattern were reviewed. Compounds not easily distinguished on the basis of spectral character alone were discarded and special attention was given to compounds commonly included on target analyte lists, such as those employed by EPA. Relative retention times were not considered in sorting TICs. TIC information has been organized to reflect a compound's relative abundance to guide future sampling/analytical activities. Data are listed according to greatest number of single contaminant detections and the range of concentrations reported for each TIC.

The ranges of concentrations reported for TICs are estimated values because authentic standards were not run to determine the absolute response factor, as is required to positively quantify compounds. TIC information is routinely assessed for the number of identifications and respective concentrations but, since they are not on the target analyte list, further quantification is not performed.

Table 4.4-2 shows that caprolactum was the TIC most often identified, with 42 tentative identifications. Caprolactum does not appear on hazardous substance lists found in the EPA 1988 List of Lists. Caprolactum is toxic by inhalation at 5 ppm in air (Sax and Lewis, 1987) and is used in the manufacture of synthetic fibers such as nylon.

The remaining compounds in Table 4.4-2 may be grouped into several distinct classes of compounds. The most important of these is the group containing target analytes for the RMA USATHAMA program, which represent duplicated identifications and suggest that some target analytes may have been overlooked. The second class of compounds includes nontarget analytes that appear on the EPA Contract Laboratory Program Target Compound List, such as dichlorobenzene and hexachlorobutadiene.

In general, the occurrence of nontarget analytes appears to be associated with chemical sources at South Plants and Basins A and F and associated to a lesser degree with Basins C, D and E. Multiple nontarget analyte occurrences in wells are usually associated with target analyte occurrence and are thought to adequately represent the water chemistry present at the sample location.

4.4.4 Conclusions for GC/MS Confirmation

GC versus GC/MS results for volatile organic analytes are within historically defined confirmation guidelines for 90 percent of the samples reviewed. In contrast, semi-volatile GC versus GC/MS results are less comparable, presumably due to differences in methodologies and instrument sensitivities used for semi-volatile analyses. Nontarget semi-volatile analytes are distributed around sources for target list analytes and potential contaminant source areas.

The results of the nontarget assessment indicated the presence of numerous nontarget analytes in ground-water samples from many areas of RMA. These nontarget analytes commonly consist of halogenated and nonhalogenated hydrocarbons. The compounds most commonly identified are substituted aromatic hydrocarbons, presumably because of their higher relative solubility in water.

4.5 Quality Assurance/Quality Control (QA/QC)

This section of the Annual Report presents and provides an interpretation of the analytical data resulting from analysis of quality control samples submitted by the field team. Ground water sampling procedures and the associated procedures for the collection and submittal of field QC samples are documented in the CMP Quality Assurance/Quality Control Plan (Stollar, 1988). These procedures stipulate the type and minimum frequency at which field derived QC samples are to be submitted to the program laboratory. The CMP Quality Assurance/Quality Control Program requires that sample duplicates (splits), field blanks, trip blanks, and rinse blanks be collected and submitted for analysis in such a fashion that the origin and prose of each quality control sample is unknown to the laboratory analyst.

Sample duplicates or splits are defined under the CMP as two identical sets of sample bottles which are submitted to the laboratory for an identical suite of analyses. Splits are collected by alternately filling sample bottles. The purpose of these split samples is to measure the analytical randomly that results from analysis of two identical samples. Field blanks require that a complete suite of sample bottles be filled in the field with distilled/deionized organic free water and submitted to the laboratory to determine if the sampling procedure has introduced extraneous contaminants into ground water samples.

A total of 810 ground water samples were collected during the winter 1987/88, spring 1988 and summer 1988 sampling programs. Of these 810 samples, 37 rinse blanks, 27 field blanks, 27 trip blanks, and 55 duplicates were taken.

Laboratory quality control data is reported to the Program Manager's Office weekly in a Quality Assurance Status Report which includes all laboratory quality control data including precision and accuracy control charts for each sample lot. quality control data are examined in relation to the criteria established during the analytical certification process. Deviations from established quality control criteria are identified by the laboratory, and appropriate corrective actions are taken. The data are then reviewed for reliability by the Program Quality Assurance officer. Any data deemed unacceptable by the Project Management Quality Assurance personnel will not be accepted for entry into the Installation Restoration Data Management System (IRDMS) database.

For purposes of discussion, the presentation of field derived quality control data has been segregated into discussions of the analyses of blank samples and duplicate samples.

4.5.1 Evaluation of Blank Data

Chemical analysis of trip, field, and rinse blanks were performed to ensure integrity of CMP data and check for contamination from field or laboratory sources. Blanks were analyzed for volatile organics, semi-volatile organics, and inorganics.

4.5.1.1 Volatile Organic Quality Control Data Review. Trip blanks, rinse blanks, and field blanks were collected and data reviewed for two rounds of ground-water monitoring. Eight different types of blank artifacts were identified in samples from these two sampling events. Table 4.5-1 summarizes the concentration and type of blank related to each of the 44 blank artifacts detected by analysis for volatile organic compounds. Blanks are listed by well location. The analytical concentration of the blank artifact that was found in the ground water sample taken from the same location is also presented on Table 4.5-1.

Data presented in Table 4.5-1 for volatile analysis show that chloroform (CHCl_3) at levels slightly above the CRL (usually less than $0.5 \mu\text{g/l}$) commonly occur in both trip and field blanks. Chloroform found in investigative samples indicates that samples 32002, 35087, 03004, 09010, 23221, 24197 and 35017 may have been affected by CHCl_3 contamination. Investigative sample concentrations are all within an order of magnitude of the concentration found in the associated field or trip blank. The analyte CHCl_3 must on this basis be considered an artifact of field operations, laboratory practices, or contamination during transport. Sample 01524 contained CHCl_3 at a concentration several orders of magnitude greater than was found in the related field blank. In this case CHCl_3 must be considered characteristic of the water chemistry present in the investigative sample. Sample 01022 related to the trip blank 01022TB containing Tetrachloroethylene (TCLEE) appears to have been unaffected by contamination. Sample 35087

contains benzene at 8.650 $\mu\text{g/l}$. This concentration is within an order of magnitude of the artifact, benzene, found in the related field blank at a concentration of 1.53 $\mu\text{g/l}$. Rinse blanks contain the highest variety and concentration of volatile artifacts. Rinse blank artifacts are of the highest interest for evaluating the potential impact of cross contamination (carry-over) due to improper decontamination of sampling equipment. The dominant artifacts found above the CRLs in rinse blanks were chloroform (0.592 to 83.7 $\mu\text{g/l}$) and chlorobenzene (1.28 to 4.20 $\mu\text{g/l}$). In addition to the above mentioned characteristic rinse blank artifacts, less common artifacts include methyl isobutyl ketone (MIBK) (19.0 $\mu\text{g/l}$) in Rinse Blank 23234RB, dimethyldisulfide (DMDS) (0.592 $\mu\text{g/l}$) in Rinse Blank 23186RB, dibromochloropropane (DBCP) (2.13 $\mu\text{g/l}$) in Rinse Blank 33033RB, TCLEE (0.967 to 1.73 $\mu\text{g/l}$) in three rinse blanks (see Table 4.5-1) and 1,1,2-trichloroethane (1,1,2-TCE) (1.77 g) in Rinse Blank 37335RB.

As mentioned previously in this section, CHCl_3 is an obvious artifact in samples related to rinse blank samples. Chlorobenzene must also be considered an artifact of poor decontamination in investigative samples 03004, 23221, and 24197. Similarly DMDS found in Sample 23186 must be considered as an artifact. Carry-over of MIBK found in Rinse Blank 23234RB does not appear to have occurred in the related investigative sample. This is also true in the case for DBCP found in Rinse Blank 33033. Samples 35017 and 37345 related to Rinse Blanks 35017RB and 37345RB both appear to contain TCLEE at nearly the same concentration as that identified in the blanks.

Overall it appears that sample contamination is a minor problem in the volatile organic analyses done for the CMP. More reliable results might be facilitated by carefully screening water to be used in decontamination of field equipment and increasing the frequency of rinse blanks to better isolate the effect of carry-over on specific investigative sample results.

4.5.1.2 Semi-volatile Organic/Pesticide quality control Data Review. Trip blanks contain no semi-volatile organic artifacts for both rounds of analysis. Field Blank 23186FB contained 8.79 $\mu\text{g/l}$ of p-chlorophenylmethyl sulfone (CPMSO_2) (Table 4.5-2). The investigative sample related to this field blank was not affected by CPMSO_2 carry-over. Rinse blanks indicate the presence of low level pesticides. Rinse Blank 23221RB, related to Well 23221, contained 117 $\mu\text{g/l}$ of dimethylmethyl phosphonate (DMMP). Rinse Blank 33033RB contained 2.13 $\mu\text{g/l}$ of DBCP. Both of the investigative samples related to these rinse blanks do not exhibit carry-over. Rinse Blank 35017 contained low levels of Dieldrin and Endrin which do not appear to have affected the related investigative sample results. Rinse Blank 36182RB contained 210 $\mu\text{g/l}$ Aldrin, 1.60 $\mu\text{g/l}$ Dieldrin, 14.0 $\mu\text{g/l}$ Endrin, and 65 $\mu\text{g/l}$ Isodrin. In the related Sample 36182 only Dieldrin is found at a concentration within one order of magnitude of the concentration found in the rinse

blank. Rinse Blank 37335RB contained 0.099 $\mu\text{g/l}$ hexachlorocyclopentadiene (Cl_6CP), but the investigative sample contained no detectable concentration for Cl_6CP .

Overall very few artifacts were identified in semi-volatile blanks. Artifacts that were found in a few of the rinse blanks do not appear to have affected any of the related investigative samples except in investigative Sample 36182. In this sample Dieldrin must be considered an artifact. Values for Aldrin, Endrin and Isodrin in this sample are several orders of magnitude greater than those values reported for the related rinse blank. These compounds must therefore be attributed to sample chemistry.

4.5.1.3 Inorganics Quality Control Data Review. The quality control review for the inorganic data was confined to the trace elements because of the importance in identifying those artifacts related to potentially hazardous elements. The dissolved solids (e.g., nitrate, sulfate, potassium, etc.) were not considered in this review because of their strong association with general water chemistry and not potentially hazardous materials.

The trip, field, and rinse blanks containing detectable concentrations of trace elements are summarized in Table 4.5-3. The table compares the concentration found in the blank to the concentration reported in the related investigative sample.

The most common artifact found in the CMP inorganic trace element analyses is mercury (Hg), which was detected in a range of concentrations from 0.108 to 0.400 $\mu\text{g/l}$. The investigative samples affected by Hg carryover are 01017, 01069, 03004, 23222, 23233, 23234, 24197, 27060, 33033, 35061, 35080, 35082 and 37342. The concentrations of Hg artifacts found in the investigative samples all are within an order of magnitude of the related quality control blank artifact concentration. Therefore, based on the EPA guidelines for the identification of artifacts, Hg must be considered as such in these samples. The wide spread presence of Hg in trip blanks, field blanks, and rinse blanks at nearly the same levels of concentration indicates that Hg contamination is related to the trace element chemistry of the water used in the preparation of the quality control samples.

Blank artifacts of zinc (Zn) have been noted in the rinse blanks in a range of concentrations from 26.7 to 132 $\mu\text{g/l}$. The investigative samples affected by Zn carryover contamination are 04014, 27072 and 36182. Carryover for Zn was confined to investigative samples related to rinse blanks. The rinse blank Zn concentrations are within an order of magnitude of the Zn concentrations observed in the related investigative samples analyzed from the previously mentioned wells. On

the basis of this criteria, zinc found in the investigative samples related to the rinse blanks listed in Table 4.5-3 be considered artifacts as a result of the decontamination procedure.

Copper (Cu) was reported in rinse blanks only at levels of concentration between 27.3 and 37.5 $\mu\text{g/l}$. Investigative sample 01017 contained Cu concentrations within an order of magnitude of the Cu level of concentration found in the related rinse blank. Therefore, the Cu concentration reported for this investigative sample can be considered an artifact.

Artifacts of fluoride (F) were found in the rinse and trip blanks at concentration levels between 568 and 2310 $\mu\text{g/l}$. The investigative samples containing F, which relate to the quality control blanks found in Table 4.5-3, are 23150, 24092 and 37345. The concentrations of F found in the related investigative samples are within an order of magnitude of the F concentrations observed in the blanks. Therefore the presence of F in these samples must be considered an artifact.

Artifacts of chloride (Cl) with a range of concentration from 0.099 to 1270 $\mu\text{g/l}$ were found in the blanks related to investigative samples 01022, 04038, 36154 and 37335. The concentrations of Cl found in the blanks and the related investigative samples are not within an order of magnitude of each other. Therefore the concentrations of Cl reported in the investigative samples can be considered representative of the actual water chemistry.

An artifact of arsenic (As) with a concentration of 3.99 $\mu\text{g/l}$ was reported in the rinse blank for investigative sample 37345. The concentration found in the related investigative sample was 3.10 $\mu\text{g/l}$. The concentrations found in the blank and the investigative sample are within an order of magnitude of each other. Therefore the As found in the investigative sample can be considered an artifact.

Based on the quality control review of the inorganic trace elements, rinse blanks, trip blanks and field blanks Hg concentrations in most cases were within an order of magnitude of the Hg concentrations reported in the related investigative samples. The distribution of Hg throughout the blanks does not allow for a positive identification of a source for the observed contamination of the investigative samples. Low level concentrations of Hg can be expected to occur in both quality control and investigative samples throughout the RMA.

Concentrations of zine, copper, fluoride and arsenic reported in investigative samples that are within an order of magnitude of the concentrations found in the related blanks are considered artifacts. There was no observed carryover in the investigative samples containing chloride (Cl) concentrations.

4.5.2 Evaluation of Data for Sample Duplicates

Duplicate samples were collected and analyzed at 55 well locations during the last year of the CMP. Results are compared to determine the reproducibility of analytical sampling media.

4.5.2.1 Inorganic Duplicate Results. The results of the duplicate samples for the inorganics will focus on the trace elements and not the dissolved solids for the same reason mentioned in the quality control review of the inorganic blanks. All the samples in which both the duplicate and the investigative sample analyte concentrations were above the CRL fell within the historical guidelines. Duplicates of arsenic, copper and mercury for investigative samples 261219, 02005, and 03002, respectively, were not confirmed based on the historical criteria. Duplicates of zinc for investigative samples 03002, 04007, 36139, 37339, 37349, 37377 and 37381 were also not confirmed based on historical guidelines.

In the case of zinc, it is possible that interferences during the analysis for inductively coupled argon plasma (ICP) metals produced erratic results either from a difference between the matrix of the standard and the sample or interference from overlapping spectral patterns.

Overall the inorganic duplicates show good agreement between the duplicates and the associated investigative samples. In the case of zinc, incorrect analytical adjustments for spectral interferences may explain the observed lack of agreement between duplicates and the associated investigative samples.

4.5.2.2 Volatile Organic Duplicate Results. In the 55 sample duplicates analyzed for volatile organics, 164 positive identifications were compared to determine the reproducibility of analytical results. Sixteen of these positive identifications were at low levels of concentration near the CRL. Unconfirmed low level results reported at concentrations within plus 100 percent of the CRL are not considered representative of analytical precision. Instrument performance, extraction efficiency, and sample homogeneity are not accurately portrayed at these low concentrations. The remaining 148 positive identifications were evaluated based on the historically established criteria of plus or minus one order of magnitude for results to be considered as replicated. Analysis of 132 of the 148 positive identifications were confirmed by this historical criteria. This means that 89 percent of all volatile results were reproducible within historically defined limits. As expected this indicates that media sampled were relatively homogeneous and deviations between investigative sample results and duplicate results are probably due to reporting error or to instrument variability.

4.5.2.3 Semi-volatile Organic Duplicate Results. Duplicate results for 110 pairs of positive target analyte identifications were available for comparison. Paired results were reported for all but 7 of the 110 positive results reported. From the remaining 103 pairs of results, 12 sets were reported at levels within plus 100 percent of the CRL. As was done in the case of volatile duplicate analyses, these results have been discarded as being detected at too low a level of concentration to accurately portray the analytical reliability of results or the homogeneity of the sampling media. This assumption is based on the definition of a CRL. This leaves 89 pairs of semi-volatile results that can be evaluated based on the historically defined criteria of plus or minus 100 percent recovery. Based on this criteria, 67 samples, or 75 percent of the semi-volatile results were positively confirmed. Most of the unconfirmed results appear at low concentrations or in highly diluted sample analyses. The relative efficiency of the solvent extraction is probably, at least in part, responsible for low level results not being duplicated within the historical guide lines. Diluted samples introduce more possible reporting errors and elevate detection limits above normal levels. Reporting errors are being investigated where they appear to have been made and elevated detection limits have been considered in comparing analytical results.

Overall the duplicate semi-volatile analytical results are acceptable and the homogeneity of the sampling media confirmed. When a low degree of correlation is found between duplicate results and investigative sample it generally appears to be related to the concentration of the reported analyte and the accuracy of the final report.

Table 4.3-1 Dieldrin Analytical Results Summary

Formation	Sampling Event	Number of Samples	Number of Detections Above CRLs	Range (µg/l)
<u>Unconfined Aquifer</u>				
	W	325	136	0.052 - 150
	Sp	216	44	0.056 - 3.60
	Su	26	23	0.053 - 5.30
	WRIR	297	115	0.062 - 8.92
<u>Confined Denver Formation</u>				
B	W	1	0	
	Sp	0	0	
	Su	0	0	
	WRIR	3	0	
VC	W	2	2	0.051 - 0.150
	Sp	1	0	
	Su	0	0	
	WRIR	1	0	
A	W	28	4	0.080 - 0.844
	Sp	7	2	0.074 - 1.60
	Su	0	0	
	WRIR	28	3	>0.050 - 0.149
IU	W	12	1	0.281
	Sp	9	1	0.203
	Su	0	0	
	WRIR	13	0	
1	W	16	3	0.066 - 0.142
	Sp	9	0	
	Su	5	1	0.058
	WRIR	16	4	0.065 - 0.411
2	W	26	4	0.056 - 0.091
	Sp	20	2	0.057 - 0.432
	Su	11	2	0.046 - 0.577
	WRIR	27	1	0.090
3	W	18	3	0.077 - 0.571
	Sp	17	0	
	Su	3	2	0.046 - 0.473
	WRIR	20	2	0.125 - 1.23

Table 4.3-1 (cont'd.)

Formation	Sampling Event	Number of Samples	Number of Detections Above CRLs	Range (µg/l)
4	W	18	1	0.069
	Sp	16	0	
	Su	1	0	
	WRIR	19	0	
5	W	10	1	0.077
	Sp	6	0	
	Su	0	0	
	WRIR	9	0	
6	W	2	0	
	Sp	1	0	
	Su	0	0	
	WRIR	2	0	
7	W	2	0	0.354
	Sp	2	1	
	Su	0	0	
	WRIR	2	0	

Total Confined Denver Formation

W	135	19	0.051 - 0.844
Sp	88	6	0.057 - 1.60
Su	20	5	0.046 - 0.577
WRIR	140	10	>0.050 - 1.23

Explanation:	Certified Reporting Limit (µg/l)
W: Winter 1987/88 (TMP/T25/T44)	0.050/0.054/0.054, 0.060
Sp: Spring 1988 (CMP)	0.050
Su: Summer 1988 (CMP)	0.050
WRIR: Water Remedial Investigation Report	0.054, 0.060

Note: Ground water from Denver Formation Zones 8 and 9 was not sampled.

Table 4.3-2 Summary of Dieldrin Concentrations for Quarterly Specific Area Monitoring

Well No.	Winter 1987/88 (µg/l)	Spring 1988 (µg/l)	Summer 1988 (µg/l)
23049	0.062	<0.050	0.096
23095	0.224	2.10	2.10
23108	0.580	0.487	0.690
23142	0.104	0.069	0.055
23179	0.091	--	0.577
23181	<0.054	<0.050	<0.050
23188	0.510	0.530	<0.050
23189	<0.054	--	<0.050
23190	<0.050	<0.050	<0.050
23191	<0.050	--	0.200
23192	<0.050	<0.050	<0.050
23220	--	0.590	2.50
23221	--	<0.050	0.053
23222	--	<0.050	<0.050
23237	--	--	0.530
23239	--	--	0.817
23241	--	--	1.50
26015	0.208	<0.050	0.235
26017	<0.050	<0.050	0.490
26019	0.150	--	0.168
26020	0.109	<0.050	0.222
26041	1.40	<0.050	1.60
26066	0.074	--	<0.050
26067	<0.050	<0.050	0.577
26071	<0.050	--	0.180
26072	<0.050	--	<0.050
26073	0.161	<0.050	0.248
26075	<0.050	--	<0.050
26083	0.365	<0.050	0.710
26084	0.057	0.432	<0.050
26085	0.920	<0.050	<0.050
26086	<0.050	--	<0.050
26127	0.346	<0.050	5.30
26129	<0.050	--	<0.050
26133	0.740	<0.050	1.40
26140	0.066	--	0.059
26142	0.571	--	0.473
26146	--	<0.050	<0.050
26148	--	3.60	<0.050
26149	--	<0.050	<0.050
26150	--	<0.050	<0.050
25153	--	<0.050	<0.050
26155	--	<0.050	<0.050
26156	--	0.058	<0.050
26157	--	--	0.730
27016	0.662	0.056	0.122

-- Not Analyzed

Table 4.3-3 Endrin Analytical Results Summary

Formation	Sampling Event	Number of Samples	Number of Detections Above CRLs	Range ($\mu\text{g/l}$)
<u>Unconfined Aquifer</u>				
	W	325	75	0.057 - 63.0
	Sp	216	17	0.080 - 4.20
	Su	26	4	0.052 - 0.690
	WRIR	297	43	0.064 - 1.51
<u>Confined Denver Formation</u>				
B	W	1	0	
	Sp	0	0	
	Su	0	0	
	WRIR	3	0	
VC	W	2	0	
	Sp	1	0	
	Su	0	0	
	WRIR	1	0	
A	W	28	1	0.068
	Sp	7	2	0.171 - 14.0
	Su	0	0	
	WRIR	28	0	
IU	W	12	2	0.101 - 0.078
	Sp	9	1	0.215
	Su	0	0	
	WRIR	13	0	
1	W	16	0	
	Sp	9	2	0.044 - 0.205
	Su	5	0	
	WRIR	16	2	>0.057 - 0.062
2	W	26	1	0.066
	Sp	20	0	
	Su	11	0	
	WRIR	27	1	0.058
3	W	18	1	0.080
	Sp	17	1	0.058
	Su	3	0	
	WRIR	20	1	0.162

Table 4.3-3 (cont'd.)

Formation	Sampling Event	Number of Samples	Number of Detections Above CRLs	Range (µg/l)
4	W	18	1	0.070
	Sp	16	0	
	Su	1	0	
	WRIR	19	0	
5	W	10	0	
	Sp	6	0	
	Su	0	0	
	WRIR	9	0	
6	W	2	0	
	Sp	1	0	
	Su	0	0	
	WRIR	2	0	
7	W	2	0	
	Sp	2	0	
	Su	0	0	
	WRIR	2	0	

Total Confined Denver Formation

W	135	6	0.066 - 0.080
Sp	88	6	0.044 - 14.0
Su	20	0	-
WRIR	140	4	>0.057 - 0.162

Explanation:

Certified Reporting Limit
 (µg/l)

W: Winter 1987/88 (TMP/T25/T44)	0.050/0.060/0.052, 0.060
Sp: Spring 1988 (CMP)	0.050
Su: Summer 1988 (CMP)	0.050
WRIR: Water Remedial Investigation Report	0.050

Note: Ground water from Denver Formation Zones 8 and 9 was not sampled.

Table 4.3-4 Dithiane/Oxathiane Analytical Results

Formation	Sampling Event	Number of Samples	Number of Detections Above CRLs	Range (µg/l)
<u>Unconfined</u>				
	W	290	63	1.90 - 4320
	Sp	216	38	1.64 - 1970
	Su	25	19	2.13 - 592
	WRIR	267	58	1.25 - 9310
<u>Confined Denver Formation</u>				
B	W	2	0	
	Sp	0	0	
	Su	0	0	
	WRIR	3	0	
VC	W	2	0	
	Sp	1	0	
	Su	0	0	
	WRIR	1	0	
A	W	28	3	1.34 - 341
	Sp	7	0	
	Su	0	0	
	WRIR	28	0	
1U	W	12	2	88.0 - 338
	Sp	9	2	83.5 - 129
	Su	0	0	
	WRIR	13	1	200
1	W	16	2	20.1 - 141
	Sp	9	0	
	Su	5	2	43.5 - 302
	WRIR	16	2	27.0 - 312
2	W	26	2	27.1 - >37.6
	Sp	20	1	163
	Su	11	1	147
	WRIR	27	2	21.5 - 102
3	W	18	0	
	Sp	17	0	
	Su	3	0	
	WRIR	20	0	

Table 4.3-4 (cont'd.)

Formation	Sampling Event	Number of Samples	Number of Detections Above CRLs	Range ($\mu\text{g/l}$)
4	W	17	0	1.68
	Sp	16	0	
	Su	1	0	
	WRIR	19	1	
5	W	9	1	4.98
	Sp	6	0	
	Su	0	0	
	WRIR	9	0	
6	W	2	0	
	Sp	2	0	
	Su	0	0	
	WRIR	2	0	
7	W	2	0	
	Sp	2	0	
	Su	0	0	
	WRIR	2	0	

Total Confined Denver Formation

W	134	10	1.34 - 341
Sp	89	3	83.5 - 163
Su	20	3	43.5 - 302
WRIR	140	6	1.68 - 312

Explanation:

Certified Reporting Limit
($\mu\text{g/l}$)

W: Winter 1987/88 (TMP/T25/T44)	1.34/1.35/1.10
Sp: Spring 1988 (CMP)	1.34
Su: Summer 1988 (CMP)	1.34
WRIR: Water Remedial Investigation Report	1.10

Note: Ground water from Denver Formation Zones 8 and 9 was not sampled.

Table 4.3-5 Benzothiazole Analytical Results

Formation	Sampling Event	Number of Samples	Number of Detections Above CRLs	Range ($\mu\text{g/l}$)
<u>Unconfined</u>				
	W	290	27	2.07 - 370
	Sp	216	4	5.88 - 18.1
	Su	26	5	6.65 - 44.6
	WRIR	266	17	1.24 - 14.6
<u>Confined Denver Formation</u>				
B	W	2	0	
	Sp	3	0	
	Su			
	WRIR			
VC	W	2	0	
	Sp	1	0	
	Su			
	WRIR	1	0	
A	W	28	2	6.49 - 48.4
	Sp	7	0	
	Su			
	WRIR	28	0	
1U	W	12	1	14.3
	Sp	9	0	
	Su			
	WRIR	13	1	3.56
1	W	16	1	13.5
	Sp	9	0	
	Su	5	0	
	WRIR	16	1	1.62
2	W	26	4	6.00 - 8.50
	Sp	19	0	
	Su	11	0	
	WRIR	27	0	
3	W	18	0	
	Sp	17	0	
	Su	3	0	
	WRIR	20	0	

Table 4.3-5 (cont'd.)

Formation	Sampling Event	Number of Samples	Number of Detections Above CRLs	Range ($\mu\text{g/l}$)
4	W	17	1	12.4
	Sp	16	0	
	Su	1	0	
	WRIR	19	1	
5	W	9	1	1.99
	Sp	6	0	
	Su			
	WRIR	9	1	
6	W	2	0	1.50
	Sp	2	0	
	Su			
	WRIR	2	0	
7	W	2	0	
	Sp	2	0	
	Su			
	WRIR	2	0	

Total Confined Denver Formation

W	134	10	1.99 - 48.4
Sp	91	0	
Su	20	0	
WRIR	140	4	1.50 - 3.56

Explanation:

Certified Reporting Limit
 ($\mu\text{g/l}$)

W: Winter 1987/88 (TMP/T25/T44)	5.00/1.14/1.14
SP: Spring 1988 (CMP)	5.00
SU: Summer 1988 (CMP)	5.00
WRIR: Water Remedial Investigation Report	1.14

Note: Ground water from Denver Formation Zones 8 and 9 was not sampled.

Table 4.3-6 Organosulfur Analytical Results

Formation	Sampling Event	Number of Samples	Number of Detections Above CRLs	Range (µg/l)
<u>Unconfined</u>				
	W	290	100	2.54 - 6320
	Sp	216	34	6.06 - 1460
	Su	25	16	10.3 - 1250
	WRIR	266	89	2.16 - 205
<u>Confined Denver Formation</u>				
B	W	2	1	21.5
	Sp	0	0	
	Su	0	0	
	WRIR	3	0	
VC	W	2	1	63.9
	Sp	1	0	
	Su	0	0	
	WRIR	1	0	
A	W	28	3	6.39 - 79.6
	Sp	7	0	
	Su	0	0	3.64 - 4.09
	WRIR	28	3	
1U	W	12	1	46.9
	Sp	9	1	92.0
	Su	0	0	1.25 - 3.16
	WRIR	13	2	
1	W	16	0	13.8
	Sp	9	1	
	Su	5	0	
	WRIR	16	1	
2	W	26	2	11.5 - 32.8
	Sp	20	1	16.6
	Su	11	0	11.9
	WRIR	27	1	
3	W	18	3	7.93 - 10.3
	Sp	17	0	
	Su	3	0	
	WRIR	20	0	

Table 4.3-6 (cont'd.)

Formation	Sampling Event	Number of Samples	Number of Detections Above CRLs	Range (µg/l)
4	W	17	1	62.9
	Sp	16	0	
	Su	1	0	
	WRIR	19	0	
5	W	9	1	3.73 14.8
	Sp	6	1	
	Su	0	0	
	WRIR	9	0	
6	W	2	1	8.88
	Sp	2	0	
	Su	0	0	
	WRIR	2	0	
7	W	2	1	6.80
	Sp	2	0	
	Su	0	0	
	WRIR	2	0	

Total Confined Denver Formation

W	134	15	3.73 - 79.6
Sp	89	4	13.8 - 92.0
Su	20	0	
WRIR	140	7	1.25 - 11.9

Explanation:	Certified Reporting Limit (µg/l)
W: Winter 1987/88 (TMP/T25/T44)	5.69/1.08/1.08
Sp: Spring 1988 (CMP)	5.69
Su: Summer 1988 (CMP)	1.15
WRIR: Water Remedial Investigation Report	1.08

Note: Ground water from Denver Formation Zones 8 and 9 was not sampled.

Table 4.3-7 Volatile Aromatic Compounds Analytical Results Summary

Formation	Sampling Event	Number of Samples	Number of Detections Above CRLs	Range (µg/l)
<u>Unconfined</u>				
	W	325	126	0.622 - 680,000
	Sp	218	53	1.04 - >122,000
	Su	26	15	1.07 - 782
	WRIR ¹	331	49	1.39 - 56,200
<u>Confined Denver Formation²</u>				
B	W	2	0	
	Sp	0	0	
	Su	0	0	
VC	W	2	1	58.8
	Sp	1	0	
	Su	0	0	
A	W	28	11	1.58 - >450
	Sp	7	4	2.68 - >81,700
	Su	0	0	
1U	W	12	4	3.32 - 90.8
	Sp	9	5	3.43 - 57.1
	Su	0	0	
1	W	16	5	1.11 - 11.6
	Sp	9	3	10.6 - 346
	Su	5	3	3.49 - 11.3
2	W	27	8	1.65 - 207
	Sp	20	9	1.05 - 8.67
	Su	11	1	6.01
3	W	18	8	2.21 - >93.9
	Sp	17	3	1.26 - 49.5
	Su	3	0	9.39
4	W	19	9	1.11 - >142
	Sp	16	4	1.66 - 2.22
	Su	1	0	

Table 4.3-7 (cont'd.)

Formation	Sampling Event	Number of Samples	Number of Detections Above CRLs	Range ($\mu\text{g/l}$)
5	W	10	6	5.46 - 50.5
	Sp	6	3	1.51 - 21.7
	Su	0	0	
6	W	2	1	12.0
	Sp	2	1	6.92
	Su	0	0	
7	W	2	1	323
	Sp	2	0	
	Su	0	0	
Total Confined Denver Formation				
	W	138	54	1.11 - >450
	Sp	89	32	1.05 - >81,700
	Su	20	4	3.49 - 11.3

Explanation:	Certified Reporting Limit ($\mu\text{g/l}$)
W: Winter 1987/88 (TMP/T25/T44)	0.820/0.620/0.580
Sp: Spring 1988 (CMP)	0.820
Su: Summer 1988 (CMP)	0.820
WRIR: Water Remedial Investigation Report	1.34

¹ Summary results for total VOAs were not compiled for the WRIR.

² Ground water was not sampled from Denver Formation Zones 8 and 9.

Table 4.3-8 Specific Area Volatile Aromatic Concentrations

Well No.	Winter 1987/88 (µg/l)	Spring 1988 (µg/l)	Summer 1988 (µg/l)
23049	70.0	76.0	<0.58
23095	<0.58	76.0	7.21
23108	<0.58	<0.58	<0.58
23142	<0.58	4.35	<0.58
23179	43.0	--	53.0
23181	2.37	1.53	<0.58
23188	<0.58	2.00	<0.58
23189	<0.58	--	<0.58
23190	<0.58	1.70	<0.58
23191	<0.58	--	<0.58
23192	13.70	<0.58	9.39
23220	--	2.44	3.26
23221	--	4.77	<0.58
23222	--	<0.58	<0.58
23237	--	--	<0.58
23239	--	--	2.34
23241	--	--	1.07
26015	<0.58	6.44	1.12
26017	<0.58	<0.58	4.55
26019	<0.58	--	<0.58
26020	2.84	<0.58	2.01
26041	132	148	15.63
26066	10.7	--	11.32
26067	<0.58	1.65	<0.58
26071	2.48	--	2.51
26072	<0.58	--	<0.58
26073	<0.58	<0.58	2.02
26075	<0.58	--	<0.58
26083	<0.58	<0.58	<0.58
26084	<0.58	<0.58	<0.58
26085	<0.58	<0.58	<0.58
26086	1.99	--	3.49
26127	1.47	2.18	3.74
26129	5.68	--	6.01
26133	562	<0.58	782.0
26140	<0.58	--	<0.58
26142	<0.58	--	<0.58
26146	--	<0.58	<0.58
26148	--	<0.58	212
26149	--	--	<0.58
26150	--	<0.58	<0.58
26153	--	1.98	<0.58
26155	--	<0.58	<0.58
26156	--	<0.58	<0.58
26157	--	--	8.30
27016	--	<0.58	<0.58

-- Not Analyzed

Table 4.3-9 Benzene Analytical Results

Formation	Sampling Event	Number of Samples	Number of Detections Above CRLs	Range (µg/l)
<u>Unconfined</u>				
	W	301	48	2.00 - 680,000
	Sp	213	27	1.27 - 51,000
	Su	26	4	7.21 - 520
	WRIR	331	36	1.49 - 25,000
<u>Confined Denver Formation</u>				
B	W	2	0	
	Sp	0	0	
	Su	0	0	
	WRIR	3	0	
VC	W	2	1	8.74
	Sp	1	0	
	Su	0	0	
	WRIR	0	0	
A	W	26	3	1.79 - 250
	Sp	7	4	1.69 - 200
	Su	0	0	
	WRIR	28	2	1.63 - 2.0
1U	W	11	1	40.0
	Sp	9	3	1.78 - 12.8
	Su	0	0	
	WRIR	13	1	1.67
1	W	15	1	11.6
	Sp	8	3	1.27 - 50.0
	Su	5	1	1.64
	WRIR	18	1	4.82
2	W	24	5	2.21 - 37.5
	Sp	20	4	1.53 - 8.67
	Su	11	1	6.01
	WRIR	29	7	1.78 - 73.8
3	W	18	4	2.21 - 13.7
	Sp	16	2	1.26 - 7.01
	Su	3	1	9.39
	WRIR	20	9	3.30 - 24.6

Table 4.3-9 (cont'd.)

Formation	Sampling Event	Number of Samples	Number of Detections Above CRLs	Range (µg/l)
4	W	18	4	2.29 - 42.8
	Sp	16	3	1.66 - 2.22
	Su	1	0	
	WRIR	20	5	3.65 - 10.3
5	W	10	2	6.03 - 9.44
	Sp	6	2	1.51 - 4.44
	Su	0	0	
	WRIR	9	2	3.05 - 4.68
6	W	2	0	
	Sp	2	0	
	Su	0	0	
	WRIR	2	0	
7	W	2	1	250
	Sp	2	0	
	Su	0	0	
	WRIR	2	0	

Total Confined Denver Formation

W	130	22	1.79 - 250
Sp	87	21	1.26 - 200
Su	20	3	1.64 - 9.39
WRIR	144	27	1.63 - 73.8

Explanation:

Certified Reporting Limit
(µg/l)

W: Winter 1987/88 (TMP/T25/T44)	1.70/1.92/1.10-1.92
Sp: Spring 1988 (CMP)	1.05
Su: Summer 1988 (CMP)	1.05
WRIR: Water Remedial Investigation Report	1.34

Note: Ground water from Denver Formation Zones 8 and 9 was not sampled.

Table 4.3-10 Chlorobenzene Analytical Results

Formation	Sampling Event	Number of Samples	Number of Detections Above CRLs	Range (µg/l)
<u>Unconfined</u>				
	W	317	108	0.620 - 41,000
	Sp	217	39	1.04 - 70,000
	Su	26	8	1.07 - 14,000
	WRIR	331	52	0.582 - 31,200
<u>Confined Denver Formation</u>				
B	W	2	0	
	Sp	0	0	
	Su	0	0	
	WRIR	3	0	
VC	W	2	1	50.1
	Sp	1	0	
	Su	0	0	
	WRIR	0	0	
A	W	28	11	1.06 - >200
	Sp	7	4	0.990 - 79,000
	Su	0	0	
	WRIR	29	1	2.33
IU	W	12	4	3.32 - 55.5
	Sp	9	2	83.5 - 129
	Su	0	0	
	WRIR	13	1	19.5
1	W	16	4	1.11 - 10.7
	Sp	9	3	9.40 - 290
	Su	5	2	3.49 - 9.68
	WRIR	18	2	3.81 - 8.62
2	W	26	3	1.65 - 170
	Sp	20	5	1.05 - 8.01
	Su	11	0	
	WRIR	29	6	0.790 - 74.7
3	W	18	6	3.50 - 81.4
	Sp	17	2	1.70 - 42.5
	Su	3	0	
	WRIR	20	6	9.50 - 33.0

Table 4.3-10 (cont'd.)

Formation	Sampling Event	Number of Samples	Number of Detections Above CRLs	Range ($\mu\text{g/l}$)
4	W	18	9	1.11 - >98.0
	Sp	16	1	2.17
	Su	1	0	
	WRIR	20	6	3.60 - 42.4
5	W	10	5	1.41 - 39.8
	Sp	6	2	1.64 - 17.3
	Su	0	0	
	WRIR	9	2	7.74 - 17.4
6	W	2	1	12.0
	Sp	2	1	6.92
	Su	0	0	
	WRIR	2	0	
7	W	2	1	40.3
	Sp	2	0	
	Su	0	0	
	WRIR	2	0	
<u>Total Confined Denver Formation</u>				
	W	136	45	1.06 - >200
	Sp	89	20	0.990 - 79,000
	Su	20	2	3.49 - 9.68
	WRIR	144	24	0.790 - 74.7

Explanation:	Certified Reporting Limit ($\mu\text{g/l}$)
W: Winter 1987/88 (TMP/T25/T44)	0.820/1.36/0.58, 1.36
Sp: Spring 1988 (CMP)	0.820
Su: Summer 1988 (CMP)	0.820
WRIR: Water Remedial Investigation Report	0.580

Note: Ground water from Denver Formation Zones 8 and 9 was not sampled.

Table 4.3-11 Total Volatile Organohalogen Compounds Analytical Results

Formation	Sampling ¹ Event	Number of Samples	Number of Detections Above CRLs	Range (µg/l)
<u>Unconfined</u>				
	W	322	223	0.568 - 463,000
	Sp	217	136	0.750 - 3,900,000
	Su	26	21	0.676 - 62,100
<u>Confined Denver Formation²</u>				
B	W	2	1	2.86
	Sp	0	0	
	Su	0	0	
VC	W	2	2	18.7 - 140
	Sp	1	0	
	Su	0	0	
A	W	28	19	0.745 - >1660 1.96 - 114,000
	Sp	7	5	
	Su	0	0	
1U	W	12	7	0.840 - 26.1 4.55 - 244
	Sp	9	5	
	Su	0	0	
1	W	16	2	10.7 - 40.1 1.36 - 7.44 9.14 - 49.5
	Sp	9	4	
	Su	5	2	
2	W	26	10	0.626 - 12.8 2.66 - 27.5 0.650 - 6.22
	Sp	20	6	
	Su	11	3	
3	W	18	5	0.759 - 5.45 1.05 - 16.8
	Sp	17	4	
	Su	3	0	

Table 4.3-11 (cont'd.)

Formation	Sampling Event	Number of Samples	Number of Detections Above CRLs	Range (µg/l)
<u>Confined Denver Formation (cont'd.)</u>				
4	W	19	4	1.00 - 15.7
	Sp	16	4	1.18 - 111
	Su	1	0	
5	W	10	3	2.31 - 127
	Sp	6	1	24.7
	Su	0	0	
6	W	2	1	10.6
	Sp	2	1	2.49
	Su	0	0	
7	W	2	1	484
	Sp	2	1	3.99
	Su	0	0	
<u>Total Confined Denver Formation</u>				
	W	137	55	0.626 - >1660
	Sp	88	31	1.05 - 114,000
	Su	20	5	0.650 - 49.5

Explanation:

Certified Reporting Limit
(µg/l)

W: Winter 1987/88 (TMP/T25/T44)

0.500-7.40/1.09-2.76/0.610-5.00

Sp: Spring 1988 (CMP)

0.500

Su: Summer 1988 (CMP)

0.500

¹ Summary results for total VOHs were not compiled for the WRIR.² Ground water from Denver Formation Zones 8 and 9 was not sampled.

Table 4.3-12 Summed Volatile Organohalogens Concentrations for Specific Areas

Well No.	Winter 1987/88 (µg/l)	Spring 1988 (µg/l)	Summer 1988 (µg/l)
23049	14,100	17,100	5320
23095	550	444	42.2
23108	<0.50	<0.50	<0.50
23142	<0.50	<0.50	0.720
23179	33,000	--	29,200
23181	<0.50	<0.50	1.35
23188	6.72	6.64	2.53
23189	<0.50	--	<0.50
23190	0.759	<0.50	<0.50
23191	<0.50	--	<0.50
23192	<0.50	<0.50	<0.50
23220	--	5400	5570
23221	--	1.37	<0.50
23222	--	<0.50	<0.50
23237	--	--	605
23239	--	--	1360
23241	--	--	230
26015	<0.50	14.9	8.41
26017	0.643	<0.50	5.47
26019	<0.50	--	0.880
26020	<0.50	<0.50	<0.50
26041	9.15	1.57	24.8
26066	10.7	--	9.14
26067	<0.50	<0.50	<0.50
26071	4.88	--	4.51
26072	<0.50	--	<0.50
26073	12.3	44.2	41.4
26075	<0.50	--	<0.50
26083	0.612	<0.50	0.680
26084	<0.50	<0.50	<0.50
26085	31.4	28.5	25.4
26086	<0.50	--	<0.50
26127	1.15	<0.50	1.52
26129	<0.50	--	6.22
26133	64,500	68,100	62,100
26140	40.1	--	49.6
26142	--	--	<0.50
26146	--	<0.50	0.650
26148	--	7820	56,600
26149	--	<0.50	<0.50
26150	--	<0.50	<0.50
26153	--	<0.50	<0.50
26155	--	<0.50	<0.50
26156	--	<0.50	<0.50
26157	--	--	43,000
27016	<0.50	<0.50	<0.50

-- Not Analyzed

Table 4.3-13 Chloroform Analytical Results

Formation	Sampling Event	Number of Samples	Number of Detections Above CRLs	Range ($\mu\text{g/l}$)
<u>Unconfined</u>				
	W	319	171	0.570 - 460,000
	Sp	217	95	0.550 - 3,900,000
	Su	26	18	0.640 - 60,000
	WRIR	332	128	0.540 - >38,800
<u>Confined Denver Formation</u>				
B	W	2	1	2.86
	Sp	0	0	
	Su	0	0	
	WRIR	3	0	
VC	W	2	2	2.73 - 22.3
	Sp	1	0	
	Su	0	0	
	WRIR	3	1	91.6
A	W	28	15	0.710 - 1000
	Sp	7	4	2.07 - 110,000
	Su	0	0	
	WRIR	26	6	1.91 - 194
IU	W	12	5	0.800 - 26.1
	Sp	9	5	2.62 - 240
	Su	0	0	
	WRIR	13	1	1.71
1	W	16	2	0.570 - 40.1
	Sp	9	4	0.980 - 3.63
	Su	5	1	48.5
	WRIR	15	4	5.18 - 26.5
2	W	25	6	0.630 - 12.8
	Sp	20	6	1.98 - 27.5
	Su	11	3	0.650 - 6.22
	WRIR	28	5	2.03 - 29.5
3	W	18	1	4.33
	Sp	17	3	1.05 - 16.8
	Su	3	0	
	WRIR	20	0	

Table 4.3-13 (cont'd.)

Formation	Sampling Event	Number of Samples	Number of Detections Above CRLs	Range ($\mu\text{g/l}$)
4	W	19	1	2.21
	Sp	16	4	1.18 - 111
	Su	1	0	
	WRIR	20	0	
5	W	10	1	2.05
	Sp	6	1	24.7
	Su	0	0	
	WRIR	9	1	6.87
6	W	2	1	2.85
	Sp	2	1	2.49
	Su	0	0	
	WRIR	2	0	3.10
7	W	2	1	480
	Sp	2	1	3.99
	Su	0	0	
	WRIR	2	0	

Total Confined Denver Formation

W	136	36	0.570 - 460,000
Sp	89	29	0.550 - 3,900,000
Su	20	4	0.640 - 60,000
WRIR	141	19	1.71 - 194

Explanation:

Certified Reporting Limit
($\mu\text{g/l}$)

W: Winter 1987/88 (TMP/T25/T44)	0.500/1.88/1.40
Sp: Spring 1988 (CMP)	0.500
Su: Summer 1988 (CMP)	0.500
WRIR: Water Remedial Investigation Report	0.500

Note: Ground water from Denver Formation Zones 8 and 9 was not sampled.

Table 4.3-14 Trichloroethane Analytical Results

Formation	Sampling Event	Number of Samples	Number of Detections Above CRLs	Range (µg/l)
<u>Unconfined Aquifer</u>				
	W	318	116	0.619 - 2400
	Sp	217	79	0.665 - 7000
	Su	26	14	0.954 - 100
	WRIR	332	100	0.710 - 2840
<u>Confined Denver Formation</u>				
B	W	2	0	
	Sp	0	0	
	Su	0	0	
	WRIR	3	0	
VC	W	2	2	3.46 - 10.6
	Sp	1	0	
	Su	0	0	
	WRIR	3	0	
A	W	28	8	0.645 - 440
	Sp	7	3	1.96 - 980
	Su	0	0	
	WRIR	26	1	5.42
1U	W	12	2	1.32 - 2.55
	Sp	9	3	1.93 - 4.43
	Su	0	0	
	WRIR	13	1	2.55
1	W	16	1	5.46
	Sp	9	1	3.70
	Su	5	1	4.95
	WRIR	15	1	3.98
2	W	26	4	0.615 - 10.8
	Sp	20	0	
	Su	11	0	
	WRIR	28	2	4.43 - 8.68
3	W	18	4	0.759 - 5.45
	Sp	17	1	2.66
	Su	3	0	
	WRIR	20	3	1.33 - 1.38

Table 4.3-14 (cont'd.)

Formation	Sampling Event	Number of Samples	Number of Detections Above CRLs	Range ($\mu\text{g/l}$)
4	W	19	4	1.00 - 13.5
	Sp	16	0	
	Su	1	0	
	WRIR	20	3	1.24 - 2.83
5	W	10	3	1.30 - 2.95
	Sp	6	0	
	Su	0	0	
	WRIR	9	0	
6	W	2	1	1.48
	Sp	2	0	
	Su	0	0	
	WRIR	2	0	
7	W	2	1	2.77
	Sp	2	0	
	Su	0	0	
	WRIR	2	0	

Total Confined Denver Formation

W	137	30	0.615 - 440
Sp	89	8	1.93 - 980
Su	20	1	4.95
WRIR	141	11	1.24 - 8.68

Explanation:	Certified Reporting Limit ($\mu\text{g/l}$)
W: Winter 1987/88 (TMP/T25/T44)	0.560/1.31/1.31
Sp: Spring 1988 (CMP)	0.560
Su: Summer 1988 (CMP)	0.560
WRIR: Water Remedial Investigation Report	0.100/1.31

Note: Ground water from Denver Formation Zones 8 and 9 was not sampled.

Table 4.3-15 Tetrachloroethylene Analytical Results

Formation	Sampling Event	Number of Samples	Number of Detections Above CRLs	Range ($\mu\text{g/l}$)
<u>Unconfined</u>				
	W	318	92	0.879 - 1700
	Sp	217	58	0.884 - 1100
	Su	26	13	1.03 - 1100
	WRIR	332	70	0.820 - 926
<u>Confined Denver Formation</u>				
B	W	2	0	
	Sp	0	0	
	Su	0	0	
	WRIR	3	0	
VC	W	2	1	65.0
	Sp	1	0	
	Su	0	0	
	WRIR	3	0	
A	W	28	6	0.829 - 26.0
	Sp	7	0	
	Su	0	0	
	WRIR	26	1	3.06
IU	W	12	2	0.848 - 2.00
	Sp	9	2	0.829 - 2.16
	Su	0	0	
	WRIR	13	0	
1	W	16	1	4.69
	Sp	9	2	1.42 - 2.48
	Su	5	2	1.06 - 4.19
	WRIR	15	1	5.70
2	W	26	2	1.21 - 2.40
	Sp	20	2	1.02 - 1.55
	Su	11	0	
	WRIR	28	1	1.54

Table 4.3-15 (cont'd.)

Formation	Sampling Event	Number of Samples	Number of Detections Above CRLs	Range (µg/l)
3	W	18	0	
	Sp	17	0	
	Su	3	0	
	WRIR	20	0	
4	W	19	0	
	Sp	16	0	
	Su	1	0	
	WRIR	20	0	
5	W	10	1	1.31
	Sp	6	0	
	Su	0	0	
	WRIR	9	0	
6	W	2	0	
	Sp	2	0	
	Su	0	0	
	WRIR	2	0	
7	W	2	1	1.98
	Sp	2	0	
	Su	0	0	
	WRIR	2	0	

Total Confined Denver Formation

W	137	14	0.829 - 65.0
Sp	89	6	0.829 - 2.48
Su	20	2	1.06 - 4.19
WRIR	141	3	1.54 - 5.70

Explanation:	Certified Reporting Limit (µg/l)
W: Winter 1987/88 (TMP/T25/T44)	0.750/2.76/1.30
Sp: Spring 1988 (CMP)	0.750
Su: Summer 1988 (CMP)	0.750
WRIR: Water Remedial Investigation Report	1.34

Note: Ground water from Denver Formation Zones 8 and 9 was not sampled.

Table 4.3-16 Dibromochloropropane Analytical Results

Formation	Sampling Event	Number of Samples	Number of Detections Above CRLs	Range ($\mu\text{g/l}$)
<u>Unconfined</u>				
	W	307	62	0.144 - 57,000
	Sp	216	21	0.221 - 93.0
	Su	22	6	0.235 - 37.0
	WRIR	299	63	0.146 - 278
<u>Confined Denver Formation</u>				
B	W	1	0	
	Sp	0	0	
	Su	0	0	
	WRIR	3	0	
VC	W	2	0	
	Sp	1	0	
	Su	0	0	
	WRIR	4	0	
A	W	22	2	0.496 - 21.0
	Sp	7	2	0.392 - 250
	Su	0	0	
	WRIR	26	1	0.517
IU	W	11	0	
	Sp	9	1	1.64
	Su	0	0	
	WRIR	13	0	
1	W	14	0	
	Sp	9	1	0.304
	Su	2	0	
	WRIR	15	0	
2	W	23	2	0.234 - 0.330
	Sp	20	1	0.36
	Su	9	0	
	WRIR	27	2	0.379 - 0.779
3	W	17	1	0.202
	Sp	17	0	
	Su	3	0	
	WRIR	20	0	

Table 4.3-16 (cont'd.)

Formation	Sampling Event	Number of Samples	Number of Detections Above CRLs	Range ($\mu\text{g/l}$)
4	W	18	0	0.191 - 0.207
	Sp	16	0	
	Su	1	0	
	WRIR	20	2	
5	W	8	0	
	Sp	6	0	
	Su	0	0	
	WRIR	9	0	
6	W	2	0	
	Sp	2	0	
	Su	0	0	
	WRIR	2	0	
7	W	1	0	
	Sp	2	0	
	Su	0	0	
	WRIR	2	0	

Total Confined Denver Formation

W	119	5	0.202 - 21.0
Sp	89	5	0.304 - 250
Su	15	0	
WRIR	141	5	0.191 - 0.779

Explanation:

Certified Reporting Limit
($\mu\text{g/l}$)

W: Winter 1987/88 (TMP/T25/T44)	0.190/0.130/0.130
Sp: Spring 1988 (CMP)	0.195
Su: Summer 1988 (CMP)	0.195
WRIR: Water Remedial Investigation Report	0.130

Note: Ground water from Denver Formation Zones 8 and 9 was not sampled.

Table 4.3-17 Specific Area Dibromochloropropane Concentrations

Well No.	Winter 1987/88 ($\mu\text{g/l}$)	Spring 1988 ($\mu\text{g/l}$)	Summer 1988 ($\mu\text{g/l}$)
23049	<0.190	<0.195	<0.195
23095	<0.130	<0.195	<0.195
23108	<0.190	<0.195	<0.195
23142	<0.190	<0.195	<0.195
23179	1.54	--	--
23181	<0.130	<0.195	<0.195
23188	<0.190	<0.195	--
23189	<0.130	--	<0.195
23190	--	<0.195	<0.195
23191	<0.190	--	--
23192	<0.190	<0.195	<0.195
23220	--	2.74	2.76
23221	--	<0.195	<0.195
23222	--	<0.195	<0.195
23237	--	--	0.235
23239	--	--	0.700
23241	--	--	<0.195
26015	<0.190	<0.195	<0.195
26017	<0.190	<0.195	<0.195
26019	<0.190	--	<0.195
26020	<0.190	0.221	<0.195
26041	--	<0.195	<0.195
26066	<0.190	--	--
26067	<0.190	<0.195	--
26071	<0.190	--	--
26072	<0.190	--	--
26073	<0.190	<0.195	<0.195
26075	<0.190	--	--
26083	<0.190	<0.195	<0.195
26084	<0.190	<0.195	<0.195
26085	<0.190	<0.195	<0.195
26086	<0.190	--	--
26127	<0.190	<0.195	<0.195
26129	<0.190	--	<0.195
26133	53.0	31.0	37.0
26140	<0.190	--	<0.195
26142	<0.190	--	<0.195
26146	--	<0.195	<0.195
26148	--	<0.195	5.19
26149	--	<0.195	<0.195
26150	--	<0.195	<0.195
26153	--	<0.195	<0.195
26155	--	<0.195	<0.195
26156	--	<0.195	<0.195
26157	--	--	8.10
27016	<0.190	<0.195	<0.195

-- Not Analyzed

Table 4.3-18 Dicyclopentadiene Analytical Results

Formation	Sampling Event	Number of Samples	Number of Detections Above CRLs	Range ($\mu\text{g/l}$)
<u>Uncertained</u>				
	W	280	58	10.6 - 12,000
	Sp	209	27	9.67 - 1800
	Su	23	11	15.3 - 1800
	WRIR	297	31	10.7 - 1200
<u>Confined Denver Formation</u>				
B	W	0	0	50.2
	Sp	0	0	
	Su	0	0	
	WRIR	3	0	
VC	W	2	1	26.2 - 56.4
	Sp	1	0	
	Su	0	0	
	WRIR	1	0	
A	W	28	0	9.73
	Sp	6	2	
	Su	0	0	
	WRIR	28	0	
IU	W	12	0	26.0
	Sp	9	1	
	Su	0	0	
	WRIR	13	0	
1	W	14	0	12.3 - 330
	Sp	9	1	
	Su	3	0	
	WRIR	15	0	
2	W	24	2	26.2
	Sp	20	1	
	Su	7	0	
	WRIR	27	0	
3	W	17	0	9.78
	Sp	17	1	
	Su	2	0	
	WRIR	19	0	

Table 4.3-18 (cont'd.)

Formation	Sampling Event	Number of Samples	Number of Detections Above CRLs	Range (µg/l)
4	W	16	0	
	Sp	15	0	
	Su	1	0	
	WRIR	20	0	
5	W	7	2	21.3 - 41.3
	Sp	6	2	13.9 - 20.0
	Su	0	0	
	WRIR	9	0	
6	W	2	0	
	Sp	1	0	
	Su	0	0	
	WRIR	2	0	
7	W	2	0	
	Sp	2	0	
	Su	0	0	
	WRIR	2	0	

Total Confined Denver Formation

W	124	5	12.3 - 330
Sp	86	8	9.73 - 56.4
Su	13	0	
WRIR	139	0	

Explanation:	Certified Reporting Limit (µg/l)
W: Winter 1987/88 (TMP/T25/T44)	5.00/9.31/9.31
Sp: Spring 1988 (CMP)	5.00
Su: Summer 1988 (CMP)	5.00
WRIR: Water Remedial Investigation Report	9.31

Note: Ground water from Denver Formation Zones 8 and 9 was not sampled.

Table 4.3-19 Diisopropylmethyl Phosphonate Analytical Results

Formation	Sampling Event	Number of Samples	Number of Detections Above CRLs	Range (µg/l)
<u>Unconfined</u>				
	W	306	125	11.5 - 9000
	Sp	204	66	19.8 - 32,000
	Su	19	16	50.5 - 990
	WRIR	294	121	11.9 - 12,100
<u>Confined Denver Formation</u>				
B	W	1	0	
	Sp	0	0	
	Su	0	0	
	WRIR	2	0	
VC	W	2	0	
	Sp	1	0	
	Su	0	0	
	WRIR	1	0	
A	W	26	2	33.3 - 1400
	Sp	7	1	2000
	Su	0	0	
	WRIR	28	1	2710
IU	W	12	2	3200 - 5900
	Sp	7	1	2500
	Su	0	0	
	WRIR	13	1	5350
1	W	14	3	67.6 - 260
	Sp	9	0	
	Su	4	1	230
	WRIR	16	4	17.0 - 286
2	W	23	2	18.0 - 1800
	Sp	17	0	
	Su	6	1	1800
	WRIR	27	3	27.0 - 767
3	W	17	1	53.7
	Sp	17	1	99.1
	Su	2	0	
	WRIR	17	1	47.1

Table 4.3-19 (cont'd.)

Formation	Sampling Event	Number of Samples	Number of Detections Above CRLs	Range ($\mu\text{g/l}$)
4	W	18	1	11.5
	Sp	15	1	19.8
	Su	1	0	
	WRIR	19	0	
5	W	9	0	
	Sp	6	0	
	Su	0	0	
	WRIR	9	1	27.0
6	W	2	0	
	Sp	2	0	
	Su	0	0	
	WRIR	2	0	
7	W	1	0	
	Sp	1	0	
	Su	0	0	
	WRIR	2	0	

Total Confined Denver Formation

W	125	11	11.5 - 5900
Sp	82	4	19.8 - 2500
Su	13	2	230 - 1800
WRIR	136	11	17.0 - 5350

Explanation:	Certified Reporting Limit ($\mu\text{g/l}$)
W: Winter 1987/88 (TMP/T25/T44)	18.5/10.1/10.5
Sp: Spring 1988 (CMP)	18.5
Su: Summer 1988 (CMP)	18.5
WRIR: Water Remedial Investigation Report	10.5

Note: Ground water from Denver Formation Zones 8 and 9 was not sampled.

Table 4.3-20 Specific Area Diisopropylmethyl Phosphonate Concentrations

Well No.	Winter 1987/88 (µg/l)	Spring 1988 (µg/l)	Summer 1988 (µg/l)
23049	430	630	>400
23095	493	450	630
23108	<18.5	<18.5	<18.5
23142	990	850	>400
23179	600	--	--
23181	<10.1	<18.5	<18.5
23188	610	870	--
23189	<10.1	--	--
23190	<18.5	<18.5	--
23191	190	--	--
23192	<18.5	<18.5	<18.5
23220	--	<18.5	160
23221	--	<18.5	<18.5
23222	--	<18.5	<18.5
23237	--	--	220
23239	--	--	>400
23241	--	--	>400
26015	99.1	370	340
26017	140	153	>400
26019	<18.5	--	--
26020	--	580	>400
26041	300	2500	>400
26066	67.6	--	--
26067	<18.5	--	--
26071	3000	--	--
26072	<18.5	--	--
26073	<18.5	<18.5	<18.5
26075	<18.5	--	<18.5
26033	<18.5	<18.5	--
26084	<18.5	<18.5	<18.5
26085	47.7	75.7	50.5
26086	260	--	230
26127	1300	990	990
26129	1800	--	1800
26133	990	830	830
26140	<18.5	--	<18.5
26142	<18.5	--	<18.5
26146	--	<18.5	<18.5
26148	--	500	500
26149	--	<18.5	--
26150	--	<18.5	--
26153	--	<18.5	<18.5
26155	--	<18.5	<18.5
26156	--	<18.5	<18.5
26157	--	--	>400
27016	<18.5	<18.5	--

-- Not Analyzed

Table 4.3-21 Arsenic Analytical Results

Formation	Sampling Event	Number of Samples	Number of Detections Above CRLs	Range (µg/l)
<u>Unconfined</u>				
	W	313	80	2.61 - >50.0
	Sp	207	41	2.91 - 75.0
	Su	15	13	2.91 - 29.1
	WRIR	291	74	2.56 - 315
<u>Confined Denver Formation</u>				
B	W	1	0	
	Sp	0	0	
	Su	0	0	
	WRIR	2	0	
VC	W	2	0	
	Sp	1	1	6.47
	Su	0	0	
	WRIR	3	1	
A	W	26	3	12.9 - >50.0
	Sp	7	2	8.08 - 17.2
	Su	0	0	
	WRIR	27	3	2.57 - 12.1
1U	W	12	2	6.57 - 23.7
	Sp	9	2	7.76 - 25.9
	Su	0	0	
	WRIR	13	1	7.43
1	W	15	2	7.33 - 7.54
	Sp	9	1	78.0
	Su	5	2	7.33 - 7.97
	WRIR	15	2	6.47 - 6.76
2	W	26	1	6.79
	Sp	20	1	12.9
	Su	8	1	7.11
	WRIR	27	2	3.42 - 6.45
3	W	18	2	3.88 - 6.14
	Sp	17	0	
	Su	2	0	
	WRIR	20	0	

Table 4.3-21 (cont'd.)

Formation	Sampling Event	Number of Samples	Number of Detections Above CRLs	Range (µg/l)
4	W	16	0	
	Sp	15	2	6.68 - >50.0
	Su	1	0	
	WRIR	19	3	4.98 - 8.08
5	W	8	3	3.23 - 12.9
	Sp	6	3	3.13 - 10.8
	Su	0	0	
	WRIR	9	3	4.94 - 22.2
6	W	2	0	
	Sp	2	0	
	Su	0	0	
	WRIR	2	0	
Total Confined Denver Formation				
	W	126	13	3.23 - >50.0
	Sp	87	12	3.13 - 78
	Su	16	3	7.11
	WRIR	139	15	2.57 - 22.2

Explanation:	Certified Reporting Limit (µg/l)
W: Winter 1987/88 (TMP/T25/T44)	2.50/2.50/2.50 , 3.07
Sp: Spring 1988 (CMP)	2.50
Su: Summer 1988 (CMP)	2.50
WRIR: Water Remedial Investigation Report	2.50

Note: Ground water from Denver Formation zones 8 and 9 was not sampled.

Table 4.3-22 Fluoride Analytical Results

Formation	Sampling Event	Number of Samples	Number of Detections Above CRLs	Range (µg/l)
<u>Unconfined</u>				
	W	302	245	1230 - 21,000
	Sp	216	165	1230 - 300,000
	Su	26	26	1600 - 180,000
	WRIR	294	211	1000 - 223,000
<u>Confined Denver Formation</u>				
B	W	1	0	
	Sp	0	0	
	Su	0	0	
	WRIR	2	1	2020
VC	W	2	2	1820 - 2290
	Sp	1	1	2810
	Su	0	0	
	WRIR	1	0	
A	W	27	24	1310 - 16,000
	Sp	7	7	1910 - 12,000
	Su			
	WRIR	28	14	1180 - 4830
IU	W	11	10	1280 - 4400
	Sp	9	9	1360 - 5050
	Su			
	WRIR	13	4	1630 - 5250
1	W	15	15	1430 - 4430
	Sp	9	9	1590 - 3330
	Su	5	5	1780 - 7600
	WRIR	16	10	1220 - 3530
2	W	25	21	1280 - 190,000
	Sp	20	18	1560 - 4430
	Su	11	11	1420 - 2750
	WRIR	27	16	1170 - 3220

Table 4.3-22 (cont'd.)

Formation	Sampling Event	Number of Samples	Number of Detections Above CRLs	Range ($\mu\text{g/l}$)
3	W	18	10	1480 - 5530
	Sp	17	15	1270 - 4810
	Su	3	3	2160 - 2790
	WRIR	20	11	*990 - 3000
4	W	18	12	1310 - 4710
	Sp	16	13	1230 - 3820
	Su	1	1	2970
	WRIR	19	14	*913 - 3190
5	W	8	6	1760 - 7280
	Sp	6	6	1810 - 7310
	Su			
	WRIR	9	6	*978 - 7870
6	W	2	2	1680 - 3050
	Sp	2	2	5180 - 6170
	Su			
	WRIR	2	2	1670 - 2490
7	W	2	2	2080 - 2380
	Sp	2	2	1650 - 2060
	Su			
	WRIR	2	2	1680 - 1820

Total Confined Denver Formation

W	129	104	1280 - 190,000
Sp	89	82	1230 - 12,000
Su	20	20	1420 - 7600
WRIR	139	80	*913 - 7870

Explanation:	Certified Reporting Limit ($\mu\text{g/l}$)
W: Winter 1987/88 (TMP/T25/T44)	1000/1000/1000, 1220
Sp: Spring 1988 (CMP)	1220
Su: Summer 1988 (CMP)	1220
WRIR: Water Remedial Investigation Report	1000, 1200, 1220

* Laboratory value reported below CRL.

Note: Ground water from Denver Formation Zones 8 and 9 was not sampled.

Table 4.3-23 Representative Concentrations for Naturally Occurring Constituents in Upgradient Alluvial Wells as Compared to a Downgradient Well Over Time (Values are in ug/l)

Analyte	Well Number 37363 (downgradient well)			Unconfined Well (Approximately 0.5 miles southeast of RMA)	Well Number (upgradient wells)***		
	Spring 1986	Fall 1986	Summer 1987	Spring 1988	12001	11001	08002
Chloride	103,000	93,200	98,600	84,000	34,000	52,000	60,000
Fluoride	<1,200	<1,200	<1,220	1,500	690	570	960
Sulfate	208,000	191,000	180,000	190,000	63,000	132,000	43,000
Calcium	99,100	50,300	105,000	84,400	67,000	139,000	112,000
Potassium	2,860	*	2,460	3,600	*	*	*
Sodium	101,000	62,800	111,000	97,000	44,000	68,000	60,000
Magnesium	20,900	14,000	23,600	22,100	*	*	*
Nitrogen	1,480	715	870	740	3,500	700	22,900
Zinc	103	<13.5	<20.1	66.3	*	*	*
Cadmium	<5.20	<3.86	<5.16	<8.40	*	*	*
Lead	<18.5	*	<18.6	<74.0	*	*	*
Chromium	<6.00	<4.51	<5.96	<24.0	*	*	*
Copper	<7.90	<0.260	<7.94	<26.0	*	*	*
Arsenic	<3.90	*	<3.07	<2.50	*	*	*
Mercury	<0.240	<0.500	<0.240	0.235	*	*	*

* Not analyzed

** Irrigation well, 70 feet deep, in Section 17, T3S, R66W (McConaghy, et al., 1964)

*** Alluvial wells near southern boundary of RMA, samples collected 1975 and 1976 (Army, RIC#82160R12)

Table 4.3-24 Specific Area Fluoride Concentrations

Well No.	Winter 1987/88 (µg/l)	Spring 1988 (µg/l)	Summer 1988 (µg/l)
23049	15,000	18,000	9,100
23095	3,390	19,000	25,000
23108	4,530	4,890	4,900
23142	3,530	5,090	4,980
23179	11,000	--	11,000
23181	<1,000	1,580	1,580
23188	2,800	5,810	7,900
23189	1,380	--	2,150
23190	1,610	2,490	2,430
23191	3,960	--	4,130
23192	2,520	2,940	2,790
23220	--	3,410	3,460
23221	--	1,660	1,600
23222	--	1,600	1,440
23237	--	--	7,500
23239	--	--	7,200
23241	--	--	11,000
26015	4,690	4,740	4,260
26017	4,240	5,500	4,660
26019	4,540	--	4,490
26020	--	5,110	4,310
26041	--	300,000	180,000
26066	4430	--	7,600
26067	190,000	1,780	1,770
26071	2,720	--	2,710
26072	1,800	--	1,730
26073	2,060	3,540	2,930
26075	1,840	--	1,780
26083	4,750	5,990	4,990
26084	2,600	2,420	1,930
26085	2,590	4,680	6,600
26086	3,240	--	3,110
26127	2,940	3,500	2,910
26129	2,890	--	2,750
26133	6,600	22,000	11,000
26140	2,640	--	2,530
26142	2,240	--	2,160
26146	--	2,590	1,650
26148	--	5,780	5,780
26149	--	1,810	1,860
26150	--	1,960	1,980
26153	--	3,360	2,970
26155	--	1,950	2,000
26156	--	1,740	1,420
26157	--	--	8,100
27016	3,480	6,410	5,660

-- Not Analyzed

Table 4.3-25 Chloride Analytical Results

Formation	Sampling Event	Number of Samples	Number of Detections Above CRLs	Range (µg/l)
<u>Unconfined</u>				
	W	311	231	77,260 - 7,400,000
	Sp	216	141	76,000 - 28,000,000
	Su	26	25	170,000 - 16,000,000
	WRIR	294	294	5,730 - 28,200,000
<u>Confined Denver Formation</u>				
B	W	1	0	
	Sp	0	0	
	Su	0	0	
	WRIR	2	2	32,800 - 185,000
VC	W	2	1	140,000
	Sp	1	1	98,000
	Su	0	0	
	WRIR	1	1	19,300
A	W	27	5	120,000 - 3,300,000
	Sp	7	4	110,000 - 2,100,000
	Su	0	0	
	WRIR	28	28	5,520 - 7,290,000
IU	W	12	3	83,000 - 1,300,000
	Sp	9	5	120,000 - 1,600,000
	Su	0	0	
	WRIR	13	12	14,300 - 1,610,000
1	W	15	5	93,000 - 2,800,000
	Sp	9	3	150,000 - 320,000
	Su	5	3	750,000 - 2,900,000
	WRIR	16	16	16,600 - 3,200,000
2	W	25	10	79,000 - 360,000,000
	Sp	20	11	77,000 - 1,200,000
	Su	11	5	94,000 - 810,000
	WRIR	27	27	5,300 - 1,560,000
3	W	18	6	84,000 - 427,000
	Sp	17	7	88,000 - 980,000
	Su	3	1	310,000
	WRIR	20	20	5,600 - 418,000

Table 4.3-25 (cont'd.)

Formation	Sampling Event	Number of Samples	Number of Detections Above CRLs	Range ($\mu\text{g/l}$)
4	W	18	5	79,500 - 400,000
	Sp	16	9	82,000 - 1,000,000
	Su	1	1	230,000
	WRIR	19	8	9,540 - 643,000
5	W	9	3	120,000 - 554,000
	Sp	6	2	86,000 - 710,000
	Su	0	0	
	WRIR	9	6	14,600 - 586,000
6	W	2	0	
	Sp	2	0	
	Su	0	0	
	WRIR	2	1	6,110
7	W	2	0	
	Sp	2	0	
	Su	0	0	
	WRIR	2	1	112,000
<u>Total Confined Denver Formation</u>				
	W	131	38	79,000 - 360,000,000
	Sp	89	42	77,000 - 2,100,00
	Su	19	10	82,000 - 2,900,000
	WRIR	139	122	5,300 - 3,200,000

Explanation:

W: Winter 1987/88 (TMP/T25/T44)
 Sp: Spring 1988 (CMP)
 Su: Summer 1988 (CMP)
 WRIR: Water Remedial Investigation Report

Certified Reporting Limit
 ($\mu\text{g/l}$)

75,000/75,000/75,000
 75,000
 75,000
 4,800

Note: Ground water from Denver Formation Zones 8 and 9 was not sampled.

Table 4.3-26 Typical Background Water Chemistry From the Denver Formation
(Values are in $\mu\text{g/l}$)

Analyte	Denver Aquifer Near Denver*	Denver Aquifer Denver Basin**	Denver Aquifer Well Located Upgradient of RMA***
Fluoride	1,600	1,200	1,400
Chloride	3,800	6,000	14,000
Sulfate	13,000	20,000	2,300
Arsenic	NA	NA	NA
Calcium	11,000	NA	51,000
Cadmium	NA	NA	NA
Chromium	NA	NA	NA
Copper	NA	NA	NA
Potassium	1,000	Na	3,000
Magnesium	400	NA	9,200
Sodium	57,000	82,000	36,000
Nitrate	50	30	8,300
Lead	NA	NA	NA
Zinc	NA	NA	NA

Source: HLA, 1988

* Selected chemical analyses of ground water from the Denver Aquifer near the City of Denver (Robson, 1984).

** Selected chemical analyses of ground water in the Denver Basin, Colorado (Van der Leeden, 1975).

*** Single Denver Formation well located approximately 0.5 mile southeast of RMA, Township 35 North, Range 66 West, Section 17 (McConaghy, 1964).

NA = Not Analyzed

Table 4.3-27 Winter 1987/88 Inorganic Summary

	Unconfined		Denver Formation	
	Range (µg/l)	Mean	Range (µg/l)	Mean
Ca	3520 - 23,000,00	201,00	3010 - 1,900,000	162,000
Cl	4940 - 7,400,000	424,000	1200 - 360,000,000	2,890,000
F	631 - 21,000	2790	688 - 190,000	4040
K	865 - 110,000	4880	385 - 17,000	2350
Mg	1170 - 760,000	64,700	668 - 390,000	37,000
Na	9940 - 20,000,000	452,000	4550 - 4,000,000	349,000
Nitrate + Nitrite	29.6 - 59,000	7600	29.9 - 28,000	2020
SO ₄	15,000 - 3,800,000	417,000	4870 - 2,780,000	374,000
Cd	5.26 - 38.0	8.63		
Cr	6.46 - 45.7	15.6	8.14 - 25.4	15.2
Cu	8.39 - 314	56.3	26.8 - 103	49.1
Hg	0.101 - 1.24	0.225	0.100 - 0.719	0.179
Pb	19.8 - 44.2	27.9		
Zn	21.2 - 368	50.5	23.0 - 274	52.7

Table 4.4-1 Organic Target Analytes Transitional Monitoring Program Ground-water Round

Target Analytes	Certified Reporting Limits (CRLs) in $\mu\text{g/l}$	
	(GC)	(GC/MS)
<u>Volatile Organics</u>		
Chlorobenzene (CLC_6H_5)	0.82	1.10
Chloroform (CHCl_3)	0.50	1.10
Carbon Tetrachloride (CCL_4)	0.99	2.10
trans-1,2-Dichloroethene	0.76	1.20
Trichloroethene (TRCLE)	0.75	1.30
1,1-Dichloroethene	0.73	2.40
1,1-Dichloroethane	0.76	1.20
1,2-Dichloroethane	0.76	1.20
1,1,1-Trichloroethane	0.76	1.0
1,1,2-Trichloroethane	0.78	1.0
Methylene Chloride	7.40	4.00
Tetrachloroethene (TCLEE)	0.75	1.30
Toluene (MEC_6H_5)	2.80	1.00
Benzene (C_6H_6)	1.70	1.00
Xylene (m-)	2.00	1.30
Ethylbenzene (ETC_6H_5)	1.40	1.20
Xylene (o,p)	3.20	1.40
Dicyclopentadiene ¹ (DCPD)	5.00	1.50
Methylisobutyl Ketone (MIBK)	4.90	1.00
Dibromochloropropane ¹ (DBCP)	0.19	3.00
<u>Semi-volatile Organics</u>		
P-Chlorophenylmethylsulfone (CPMSO_2)	7.46	7.20
P-Chlorophenylmethylsulfoxide (CPMSO)	11.50	29.00
P-Chlorophenylmethylsulfide (CPMS)	5.69	17.00
1,4-Dithiane (DITH)	1.34	21.00
1,4-Oxathiane (OXAT)	2.38	7.90
Dimethyldisulfide	0.55	13.50
Aldrin	0.05	7.50
Endrin	0.05	8.00
Dieldrin	0.05	4.70
Isodrin	0.05	3.70
Hexachlorocyclopentadiene (HCCPD or CLC_6CP)	9.40	0.10
p,p'-DDE	0.05	6.10
p,p'-DDT	NA	9.20
Diisopropylmethylphosphonate (DIMP)	29.30	14.00
Dimethylmethylphosphonate (DMMP)	18.50	33.00
Dibromochloropropane ¹ (DBCP)	0.19	19.00
Dicyclopentadiene ¹ (DCPD)	5.00	7.30

NA = No certified reporting limit specified for this analyte.

¹ Compound analyzed by both volatile and semi-volatile GC/MS methods.

Table 4.4-2 Tentatively Identified Compounds Indexed by Number of Identifications

Compound Name	Number of IDs	Range of Concentration (µg/l)
Caprolactam	42	13-8810
1,1,2,2-Tetrachloroethane	23	6-67
n-Eicosane	21	7-358
n-Nonadecane	20	7-378
Xylene	19	6-9000
n-Hexadecane	19	19-1060
Tetrahydrofuran	19	3-2180
Dichlorobenzene	18	7-153,000
Tetrachloroethene	17	3-370
Hexadecanoic Acid	16	6-69
n-Heneicosane	16	7-111
Cyclopentanone	16	5-182
Pentadecane	15	23-504
2,6,10,14-Tetramethylhexadecane	14	10-187
3,5-Dimethyl-1,2,4-trithiolane	13	7-71
n-Tetradecane	12	9-120
Chlorobenzene	12	3-7900
n-Heptadecane	11	11-563
1,1,2-Trichloroethane	10	6-27
n-Octadecane	9	7-382
Dodecanoic Acid	8	9-287
Tetradecanoic Acid	8	6-87
2,6,10,14-Tetramethyl pentadecane	7	6-219
Methylsulfoxylbenzene	7	9-195
Docosane	7	6-53
Ethyl,methyl,benzene	7	7-547
Dimethylnaphthalene	6	9-16,000
Octadecanoic Acid	6	9-99
Octadecanamide	6	12-54
Toluene	6	13-3630
Molecular Sulfur	6	22-1090
Trimethylbenzene	6	8-136
Hexachlorobutadiene	5	8-92
Ethanol, 2-[2-(2-butoxyethoxy) ethoxy]	5	16-110
Decanoic Acid	5	15-30
Methylpropylbenzene	5	14-98

Table 4.4-2 (cont'd.)

Compound Name	Number of IDs	Range of Concentration ($\mu\text{g/l}$)
1,3-dithiolane-2-thione	5	9-29
1,3-diothiolane	4	12-73
1,4-dithiane	4	13-133
Thiophene	3	27-58
Biphenyl-01	3	7-27
Trimethylnaphthalene	3	7000-13,000
2-Propanone (acetone)	3	10-40
Tetrachloroethane	3	11-90
4-Hydroxy-4-methyl-2-pentanone	3	13-453
Ethyl Benzene	3	15-2680
Dimethylmethyl Phosphate	3	318-8680
Bis(1-methylethyl)ester phosphonic Acid	3	24-1100
Chloromethylphenol	3	31-398
Trichlorobenzene	3	11-45
Methyl Naphthalene	3	16-6050
Tetrachlorobenzene	2	9-19
Diphenyl Ether	2	9-17
Benzoic Acid Alkyl Ester	2	7-11
Isobutylbenzene	2	
n-Butylbenzenesulfonamide	2	6-7
Ethyl dimethyl Benzene	2	49-51
Ethanol, 1-(2-butoxyethoxy)	2	9-20
Chloroform	1	4
3,4-Dimethyl Pyridine	1	13
1,2-Dichloropropene	1	33
Tetrachlorophenol	1	16
1,2-Dichloroethane	1	11
Pentachlorophenol	1	65
Pyridine	1	15
1,2-Dichloroethene	1	13
Acetophenone	1	22
n-Nitrosodipropylamine	1	14
Tetramethylbenzene	1	59
Naphthalene	1	57

Table 4.5-1 Volatile Organic Quality Control Samples

Sample ID	Blank Artifact Concentration ($\mu\text{g/l}$)	Chemical Abbreviation	Related Investigative Sample Concentration ($\mu\text{g/l}$)
Trip Blanks (27 Collected)			
01022TB	10.736	CHCl_3	<0.500
	0.901	TCLEE	<0.750
23108TB	0.599	CHCl_3	<0.500
23222TB	0.595	CHCl_3	<0.500
32002TB	0.636	CHCl_3	2.930
35082TB	0.580	CHCl_3	<0.500
35087TB	0.590	CHCl_3	1.600
37358TB	0.568	CHCl_3	<0.500
Field Blanks (27 Collected)			
01524FB	1.170	CHCl_3	230.000
23108FB	0.618	CHCl_3	<0.500
23186FB	2.170	CHCl_3	<0.500
23222FB	0.622	CHCl_3	<0.500
23233FB	0.768	CHCl_3	<0.500
32002FB	0.858	CHCl_3	2.930
33578FB	0.575	CHCl_3	<0.500
35082FB	0.767	CHCl_3	<0.500
35087FB	0.672	CHCl_3	1.600
	1.530	C_6H_6	8.650
37361FB	1.190	CHCl_3	<0.500
Rinse Blanks (37 Collected)			
03004RB	43.0	CHCl_3	111.000
	2.640	CLC_6H_5	2.170
09010RB	83.7	CHCl_3	5.940
	3.280	CLC_6H_5	<0.820
23186RB	0.592	DMS	0.550
23221RB	0.76	CHCl_3	1.370
	3.070	CLC_6H_5	4.770
23234RB	1.910	CHCl_3	<0.500
	2.50	CLC_6H_5	<0.820
	19.0	MIBK	<4.900
24197RB	4.510	CHCl_3	3.520
	1.68	CLC_6H_5	1.050
33033RB	2.13	DBCP	<0.190

Table 4.5-1 cont'd.

Sample ID	Blank Artifact Concentration ($\mu\text{g/l}$)	Chemical Abbreviation	Related Investigative Sample Concentration ($\mu\text{g/l}$)
<u>Rinse Blanks</u> (continued)			
35017RB	3.18	CHCl_3	3.630
	1.70	CLC_6H_5	<0.820
	1.06	TCL E_6	1.420
35061RB	1.28	CLC_6H_5	<0.820
	1.73	TCL E_6	<0.750
36154RB	4.20	CLC_6H_5	24.0
37308RB	3.67	CLC_6H_5	<0.820
37335RB	38.10	CHCl_3	<0.500
	1.77	112TCE	<0.780
37342RB	2.110	CLC_6H_5	<0.820
37345RB	17.50	CHCl_3	0.707
	0.967	TCL E_6	0.962

TB trip blank
 RB rinse blank
 FB field blank

Table 4.5-2 Semi-volatile Organics and Pesticide Quality Control Samples

Sample ID	Blank Artifact Concentration ($\mu\text{g/l}$)	Chemical Abbreviation	Related Investigative Sample Concentration ($\mu\text{g/l}$)
<u>Trip Blanks</u>			
No semi-volatile artifacts were identified in trip blanks for the CMP.			
<u>Field Blanks</u>			
23186FB	8.79	CPMSO2	<7.460
<u>Rinse Blanks</u>			
23221RB	117	DMMP	<18.50
33033RB	2.13	DBCP	<0.190
35017RB	0.059	DLDRN	<0.050
	0.044	ENDRN	<0.050
36182RB	0.433	ALDRN	210
	0.077	DLDRN	1.60
	0.175	ENDRN	14
	0.140	ISODR	65
37335RB	0.099	CL6CP	<0.048

FB field blank
TB trip blank

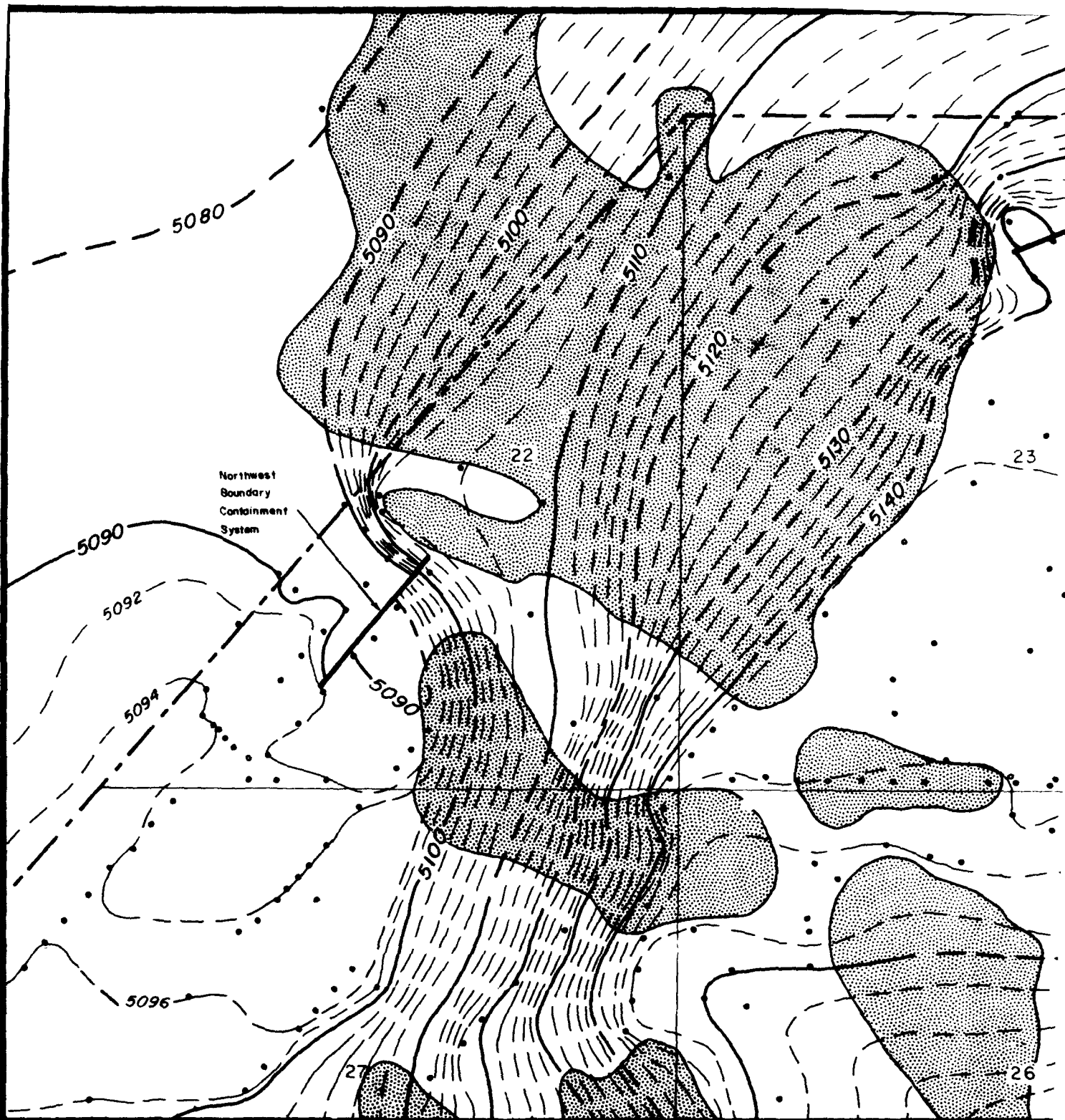
Table 4.5-3 Inorganic Summary of Blanks Quality Control Review for Trace Elements

Sample ID	Blank Artifact Concentration ($\mu\text{g/l}$)	Chemical/ Abbreviation	Related Investigative Sample Concentration ($\mu\text{g/l}$)
<u>Trip Blanks</u>			
01022TB	1050	Cl	12000
23108TB	0.188	Hg	<0.100
23150TB	652	F	4570
23186TB	330000	Mg	19200
	52.7	Zn	<22.0
23186TB	0.12	Hg	0.254
24092TB	568	F	2450
26020TB	24.9	Zn	<22.0
35082TB	0.111	Hg	0.182
37358TB	516	F	<1220
<u>Field Blanks</u>			
01069FB	0.305	Hg	0.190
04038FB	1270	Cl	63000
23222FB	0.120	Hg	0.206
	27.9	Zn	<22.0
35080FB	0.152	Hg	0.109
<u>Rinse Blanks</u>			
01017RB	27.3	Cu	26.0
	0.117	Hg	0.106
03004RB	0.229	Hg	0.216
04014RB	0.229	Hg	<0.100
	132	Zn	43.10
23234RB	0.263	Hg	0.212
24197RB	0.144	Hg	0.467
25013RB	37.5	Cu	<26.0
	38.6	Zn	<22.0
27060RB	0.170	Hg	0.223
27072RB	31.4	Cu	<26.0
	26.7	Zn	29.8
33033RB	0.108	Hg	0.164
35017RB	0.282	Hg	<010
35061RB	0.312	Hg	0.177
35054RB	4.2	Cl	>19999
36182RB	34.0	Cu	<26.0
	45.9	Zn	35.9
37308RB	0.253	Hg	<0.48
37335RB	0.099	Cl	111000
	1060	F	<1220
	0.229	Hg	<0.48
	5920	Mg	13900

Table 4.5-3 (cont'd.)

Sample ID	Blank Artifact Concentration ($\mu\text{g/l}$)	Chemical/ Abbreviation	Related Investigative Sample Concentration ($\mu\text{g/l}$)
<u>Rinse Blanks (cont'd.)</u>			
37342RB	0.234	Hg	0.360
37343RB	0.411	Hg	<0.48
37345RB	3.99	As	3.10
	2310	F	1240
	0.374	Ha	<0.48
	788	Mg	17900
37346RB	0.345	Hg	<0.24

TB trip blank
 RB rinse blank
 FB field blank



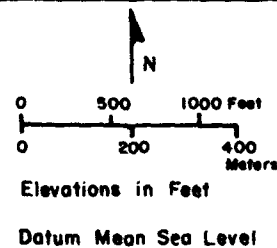
EXPLANATION

— 5146 — Equipotential Contour,
Dashed where Inferred

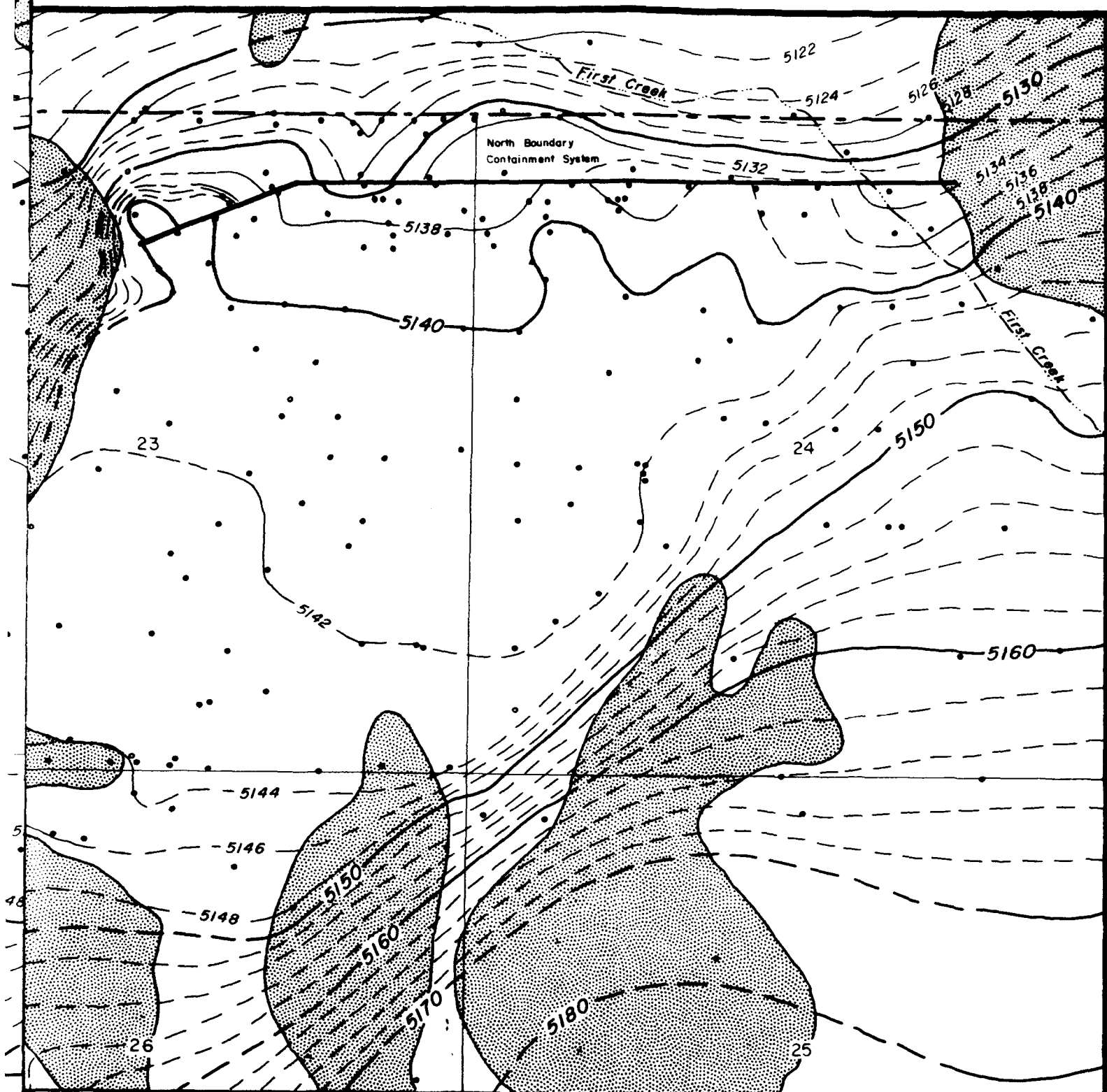


General Areas of Unsaturated
Alluvium

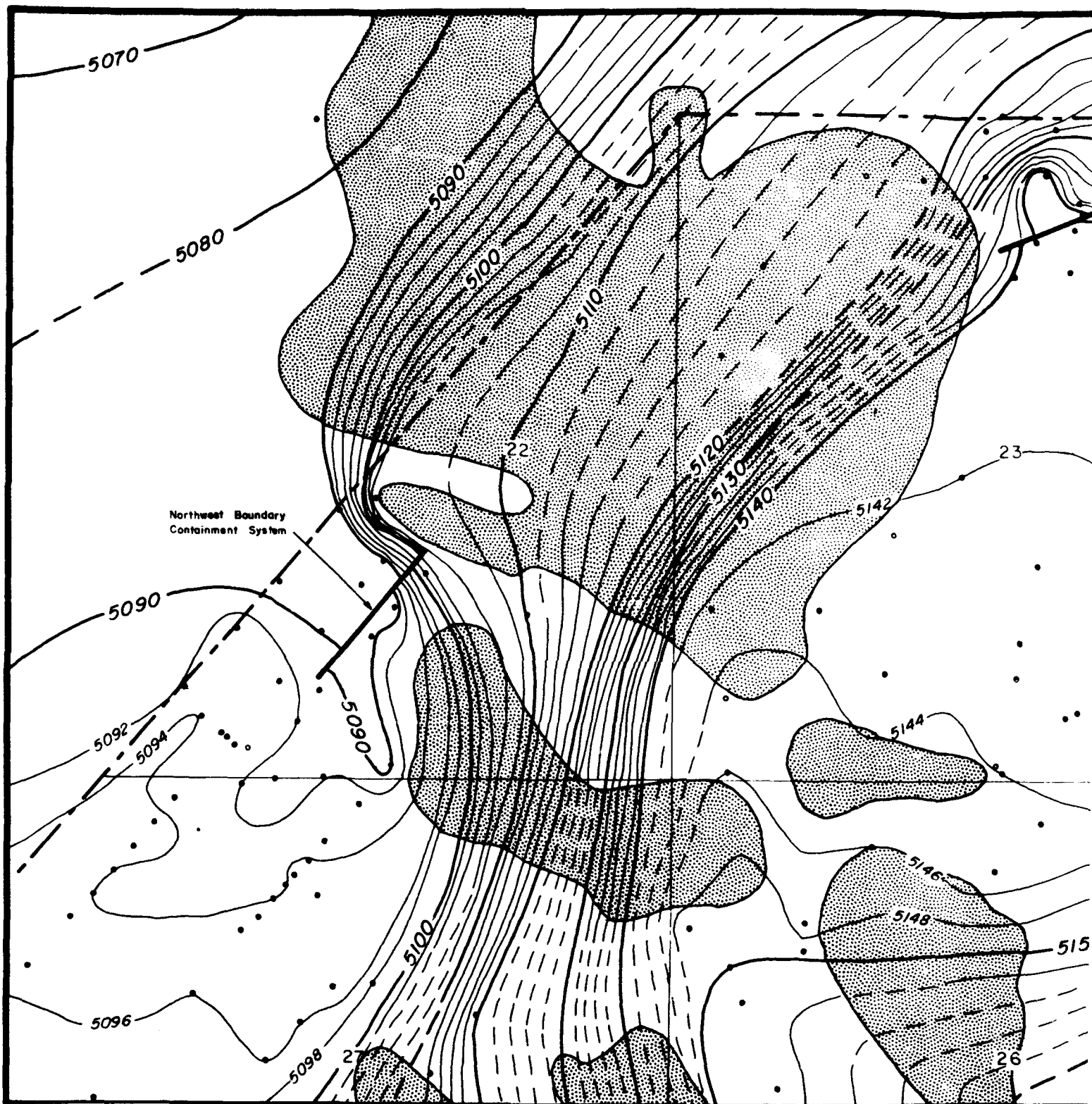
- Well or Piezometer Location
Yielding Unconfined Water
Level Elevation
 - Dry Unconfined Well or Piezometer
Location
- Contour Interval Equals 2 Feet



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<p> 1000 Feet 400 Meters Sea Level </p>	<p>Prepared for:</p> <p>Program Manager's Office for Rocky Mountain Arsenal Aberdeen Proving Ground, Maryland</p>	<p>FIGURE 4.1-1</p> <p>CMP Unconfined Water Table Elevation Contour Map of Boundary Systems Area Winter 1987/88</p> <p>Prepared by: R.L. Stollar and Associates, Inc. Harding Lawson Associates</p>
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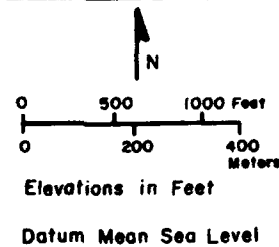
EXPLANATION

5146 Equipotential Contour,
Dashed where Inferred



General Areas of Unsaturated
Alluvium

- Well or Piezometer Location
Yielding Unconfined Water
Level Elevation
 - Dry Unconfined Well or Piezometer
Location
- Contour Interval Equals 2 Feet

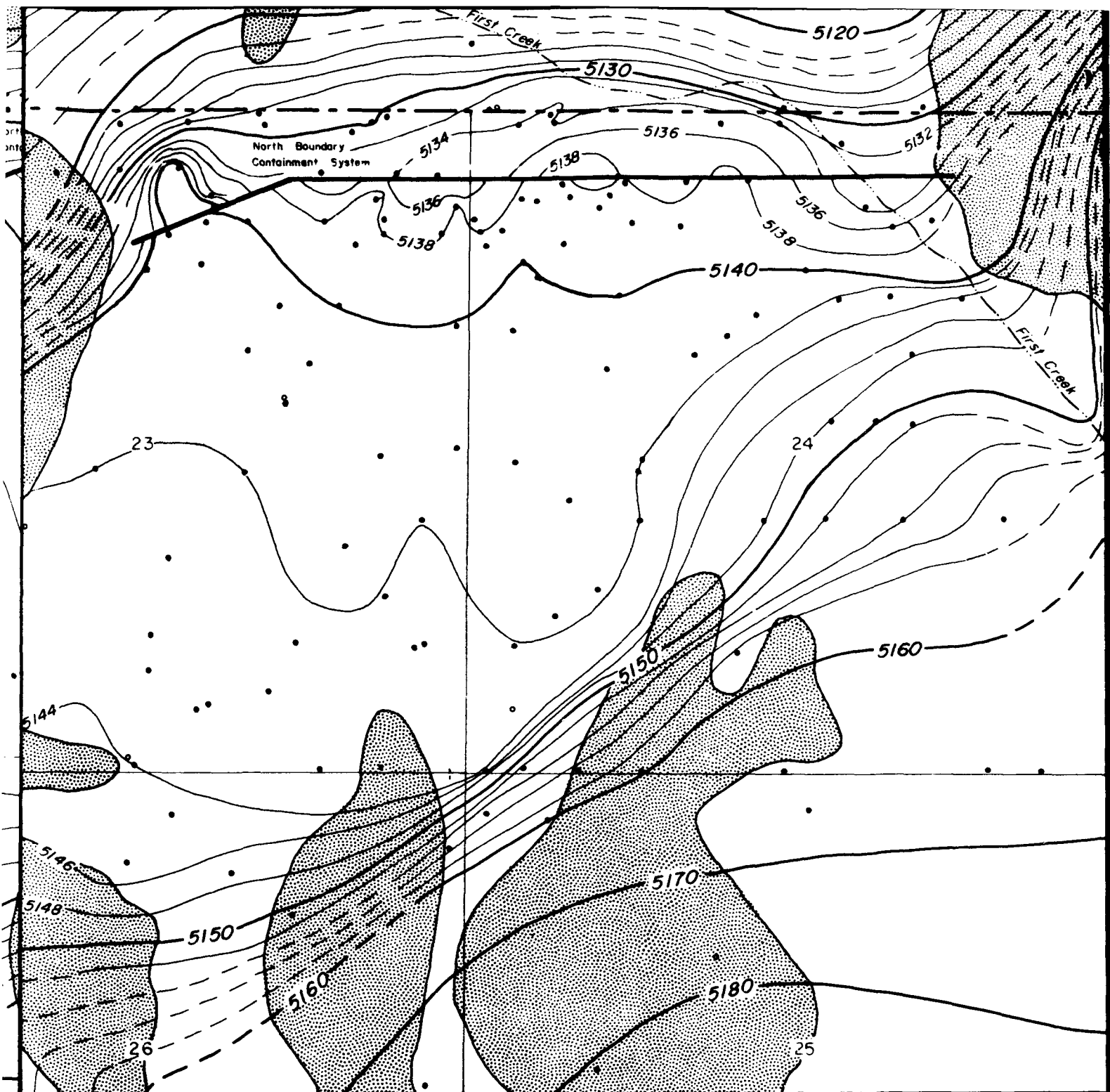


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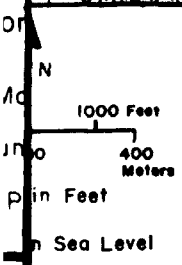
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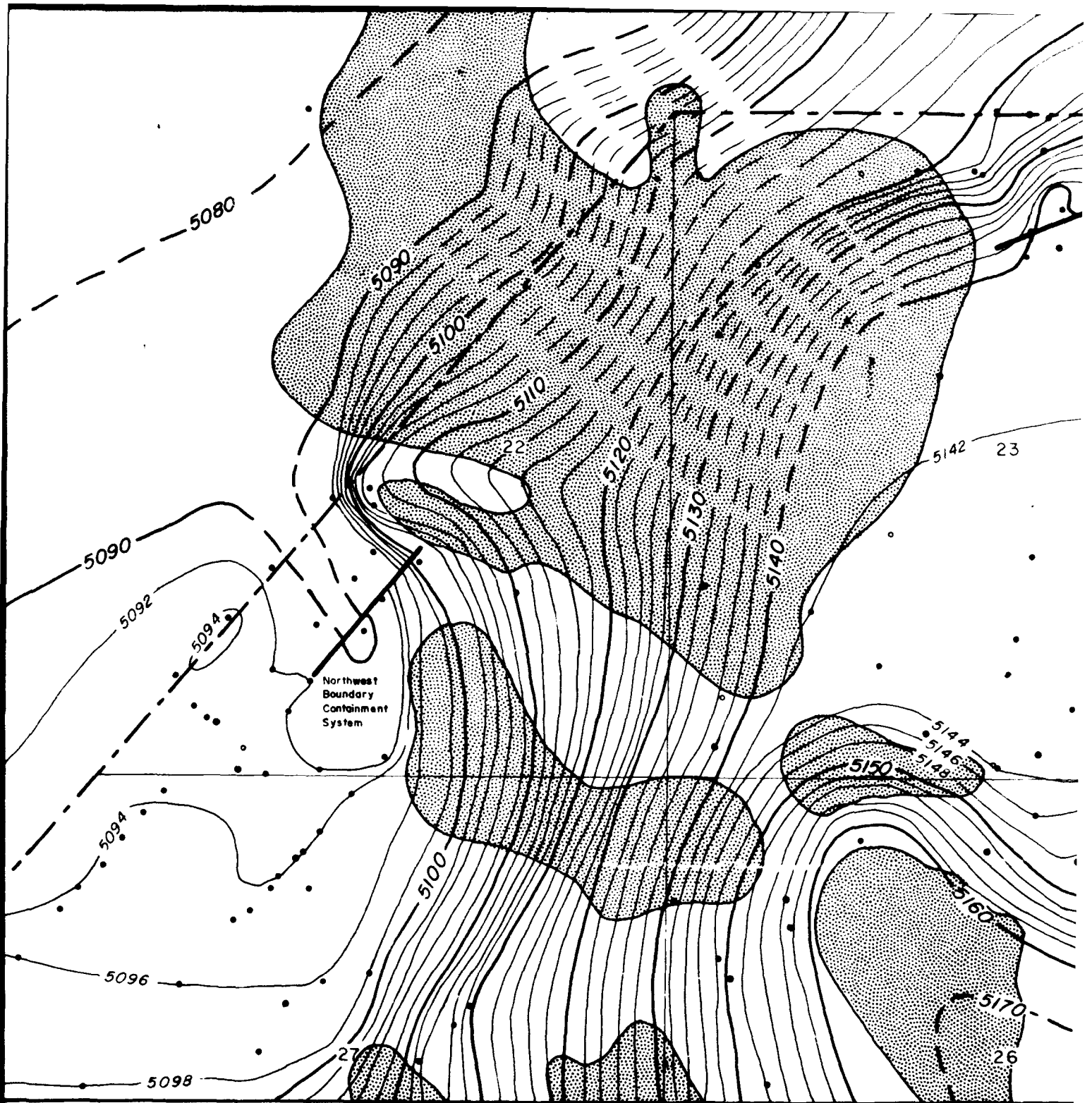
Program Manager's Office for
Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

FIGURE 4.1-2

CMP Unconfined Water Table Elevation
Contour Map of Boundary Systems Area
Spring 1988

Prepared by : R.L. Stollar and Associates, Inc.
Harding Lawson Associates





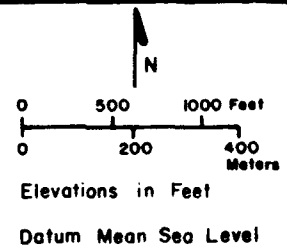
EXPLANATION

5146— Equipotential Contour,
Dashed where Inferred



General Areas of Unsaturated
Alluvium

- Well or Piezometer Location
Yielding Unconfined Water
Level Elevation
 - Dry Unconfined Well or Piezometer
Location
- Contour Interval Equals 2 Feet

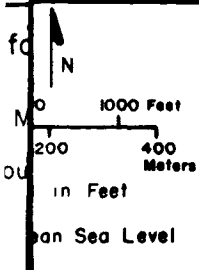
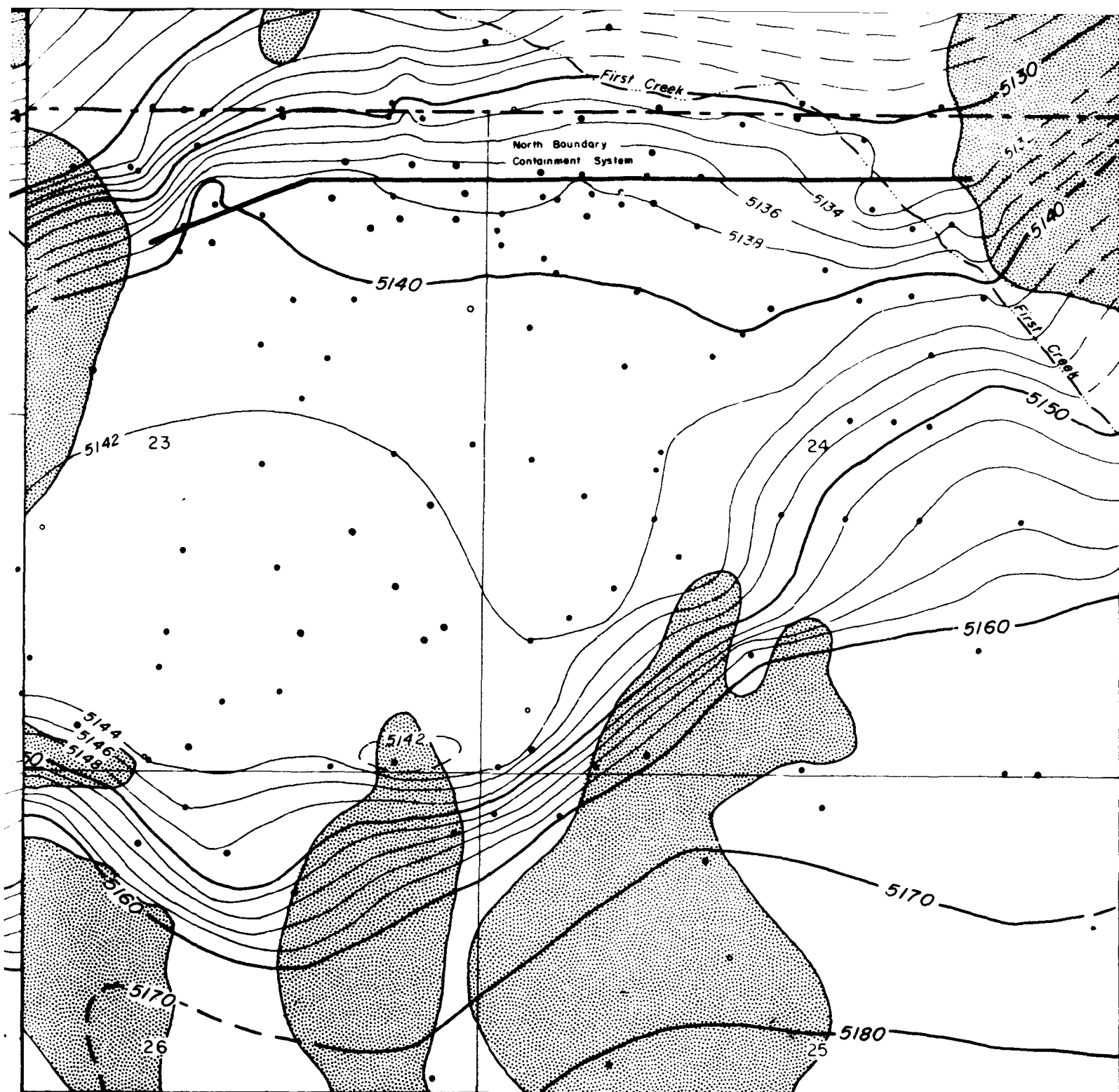


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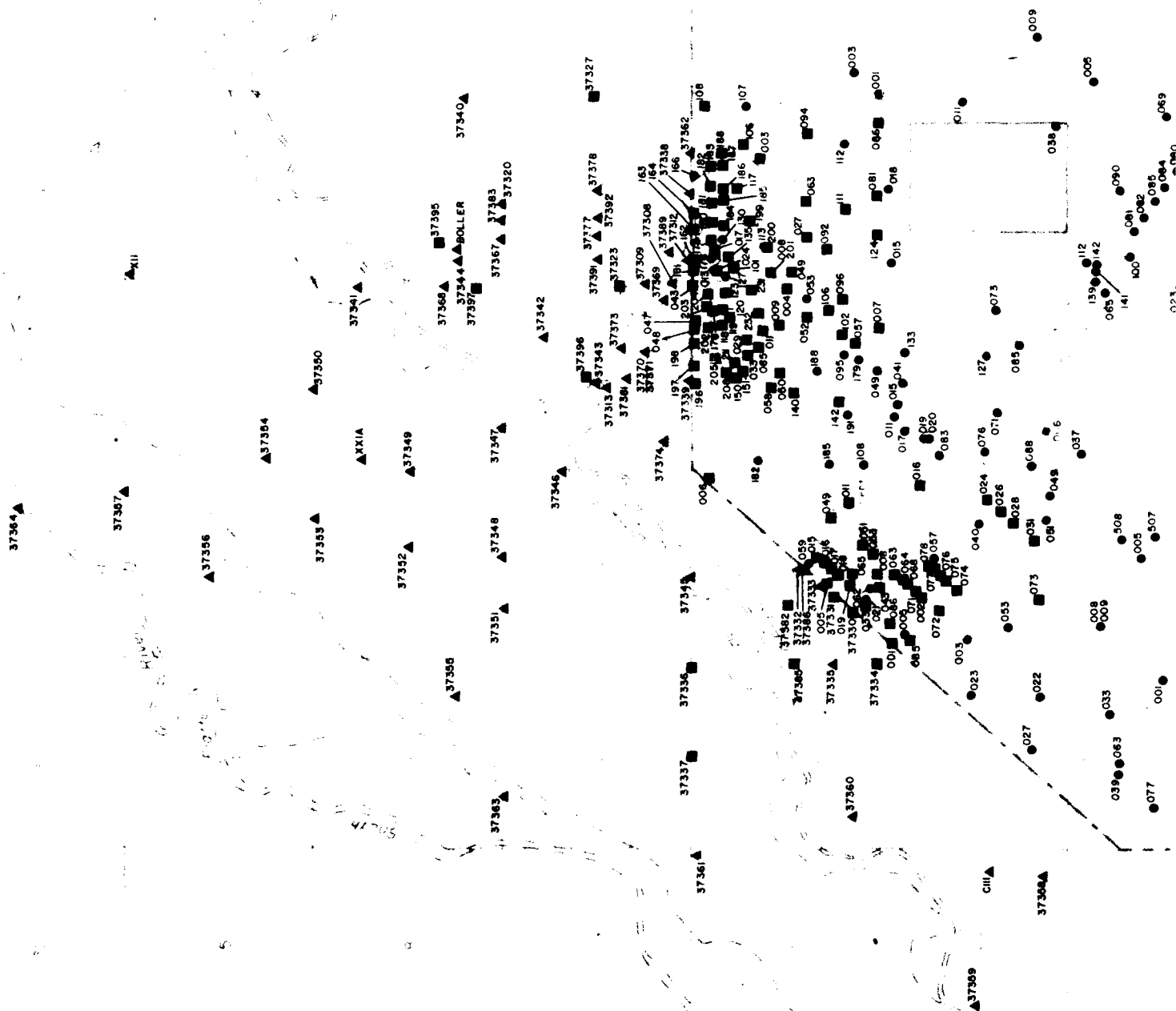
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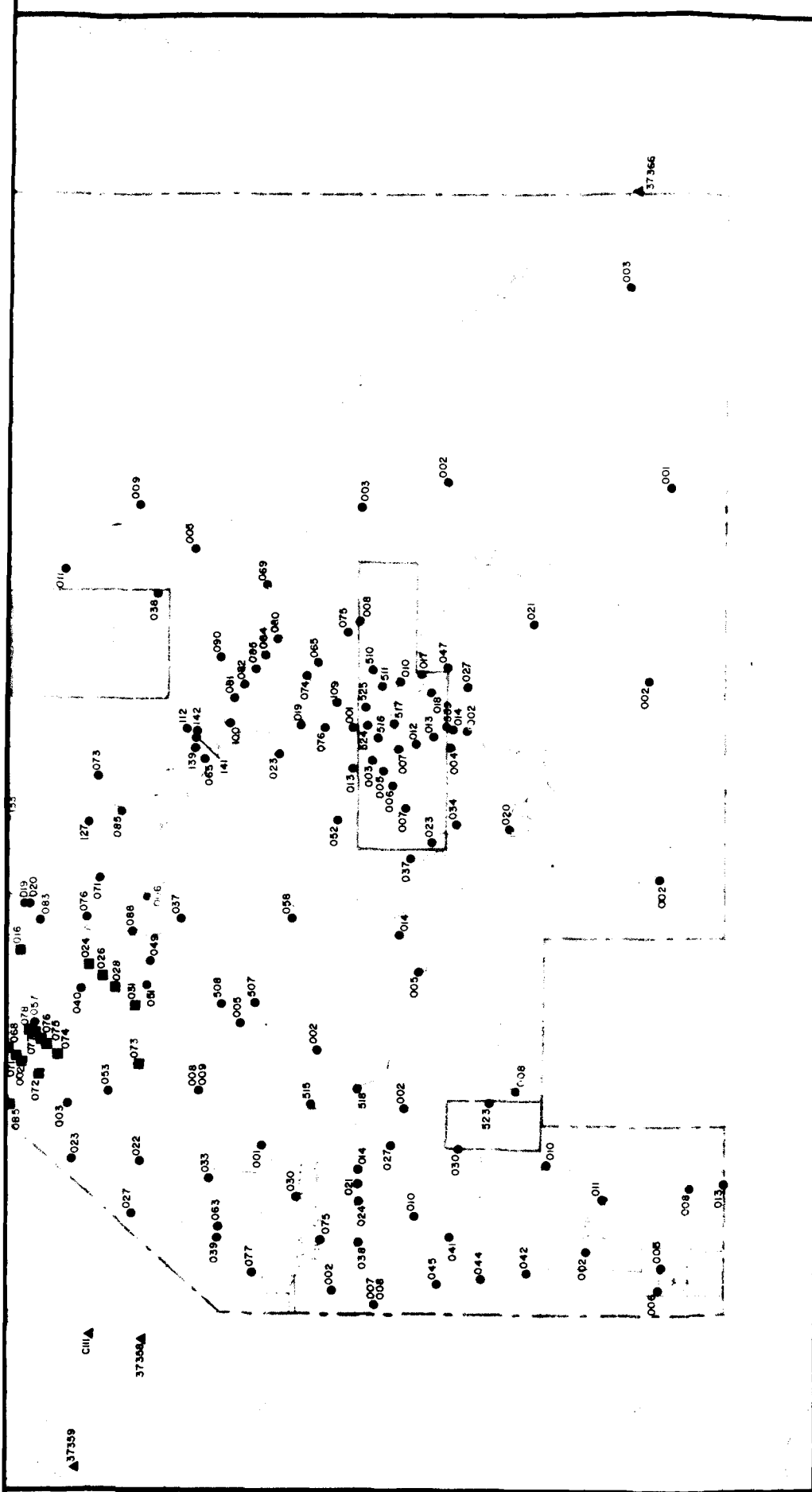
Program Manager's Office for
Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

FIGURE 4.1-3

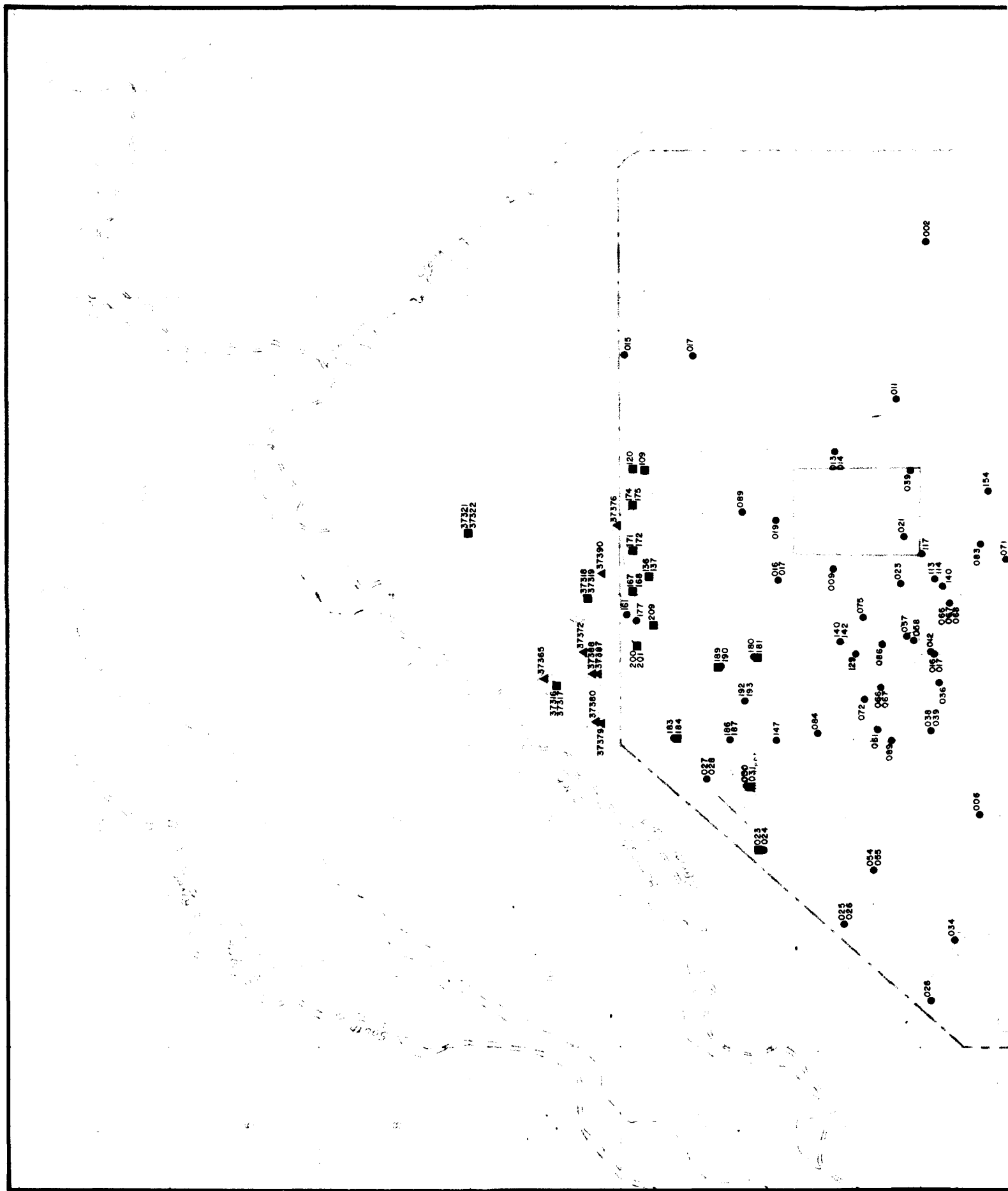
CMP Unconfined Water Table Elevation
Contour Map of Boundary Systems Area
Summer 1988

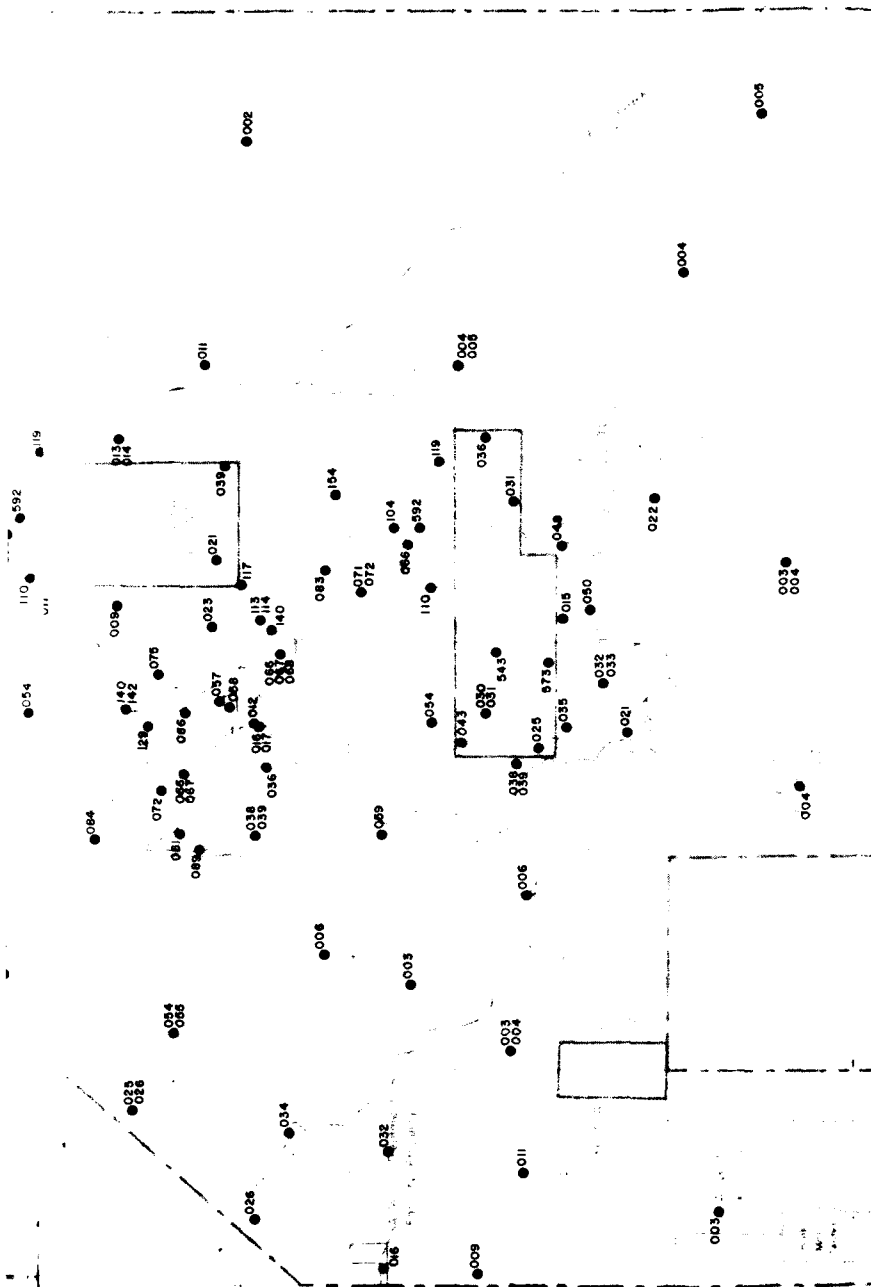
Prepared by : R.L. Stollar and Associates, Inc.
Harding Lawson Associates





<p>Prepared for:</p> <p>Program Manager's Office for Rocky Mountain Arsenal Aberdeen Proving Ground, Maryland</p>	<p>FIGURE 4.3-1</p> <p>Winter 1987/88 Well Sampling Network Unconfined Ground-Water Flow System</p> <p>CMP Ground - Water Monitoring Annual Report Prepared by: R.L. Stollar & Associates Inc. Harding Lawson Associates</p>
<p><u>Explanation</u></p> <p>Unconfined Well Location and Well Identification Number</p> <p>● 002 TMP</p> <p>▲ 37312 Task 44</p> <p>■ 058 Task 25</p>	<p>0 4000 8000 Feet</p> <p>0 1000 2000 Meters</p>





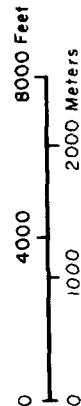
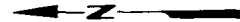
Prepared for:
 Program Manager's Office for
 Rocky Mountain Arsenal
 Aberdeen Proving Ground, Maryland

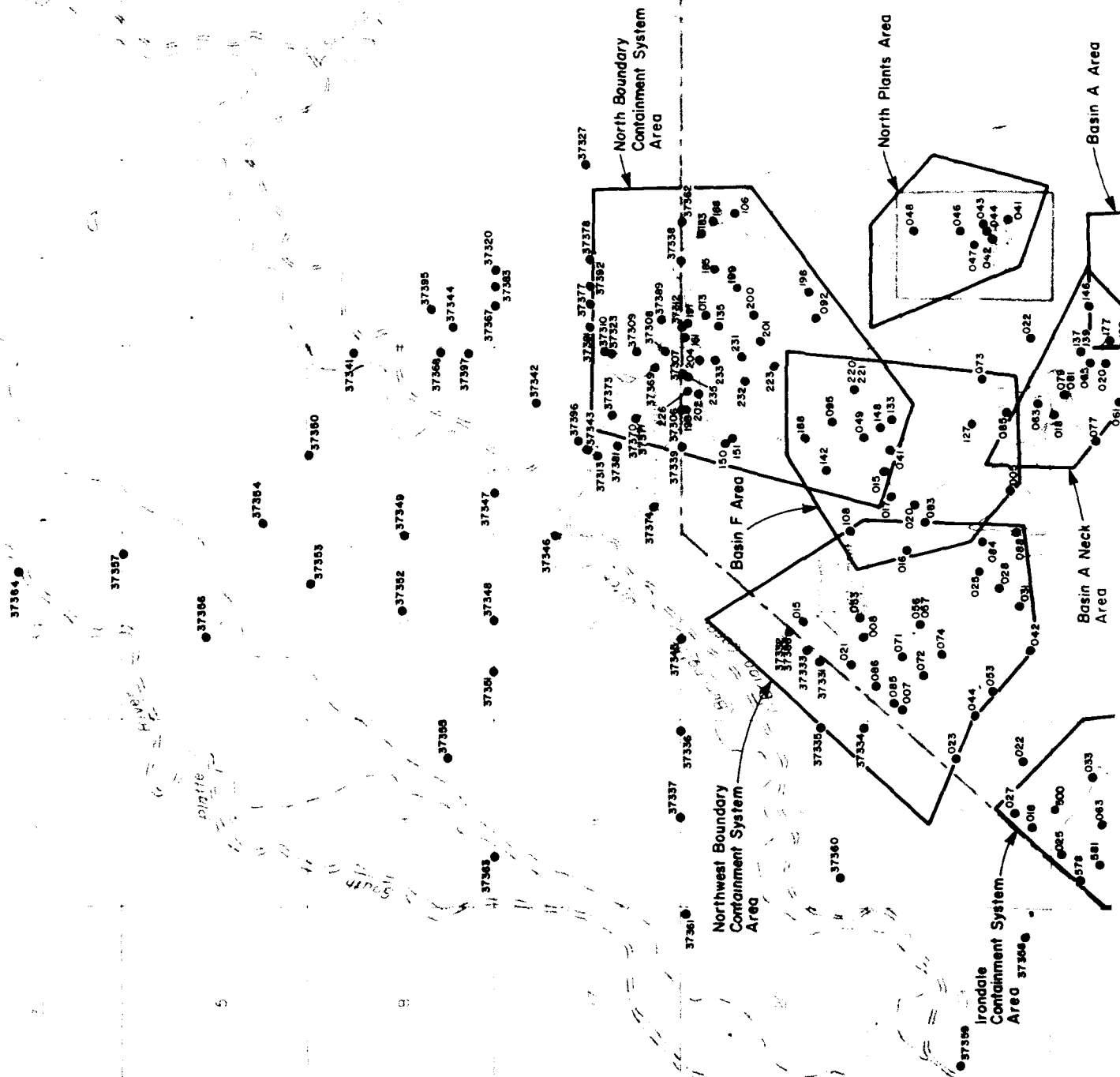
FIGURE 4.3-2
 Winter 1987/88 Well Sampling Network
 Denver Formation Ground-Water Flow System
 CMP Ground - Water Monitoring Annual Report
 Prepared by: R.L. Stollar & Associates Inc.
 Harding Lawson Associates

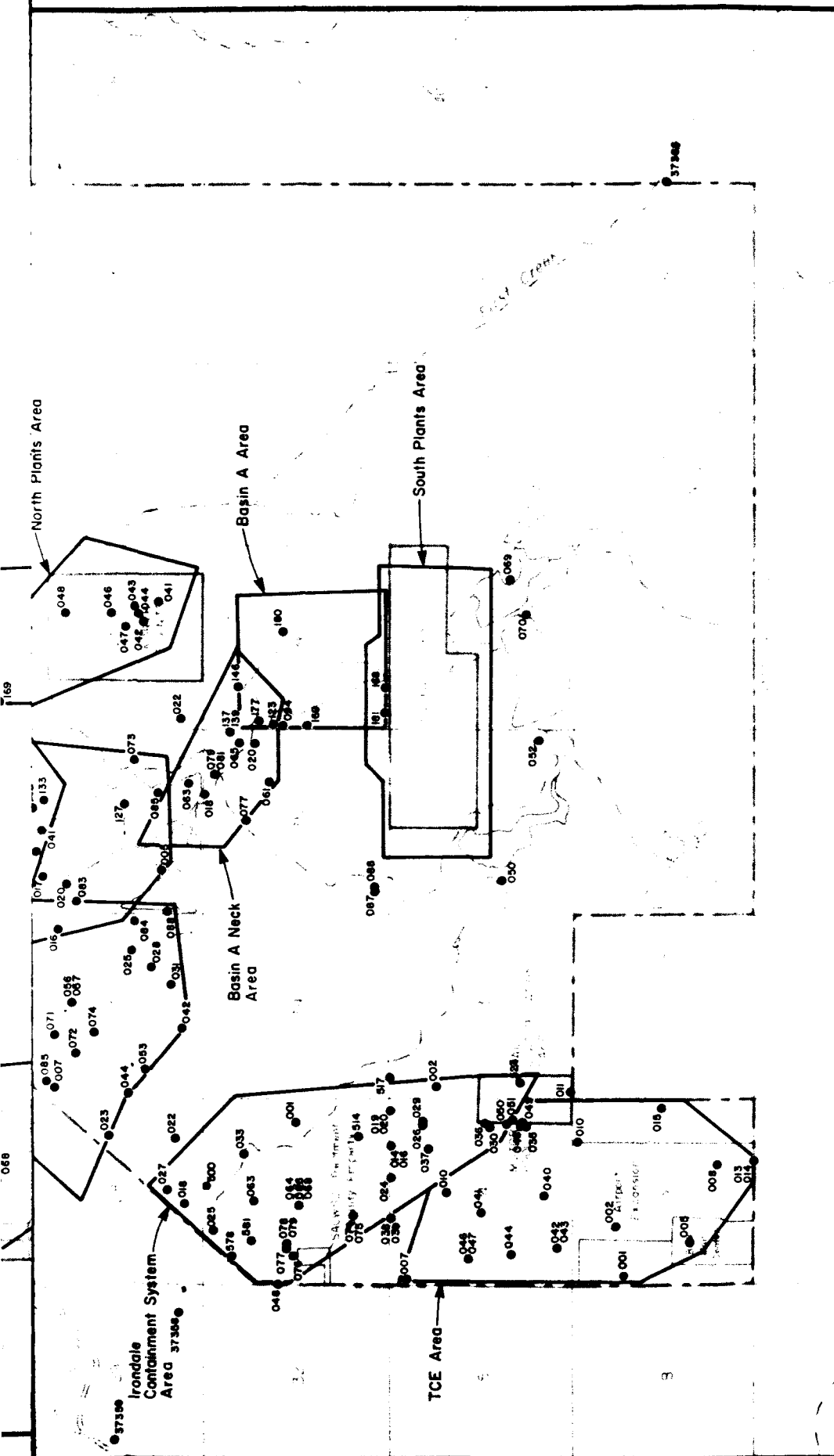
Explanation

Denver Formation Well Location and Well
 Identification Number

- 004 TMP
- ▲ 37380 Task 44
- 024 Task 25







Explanation

- Unconfined Well Location and Well Identification Number

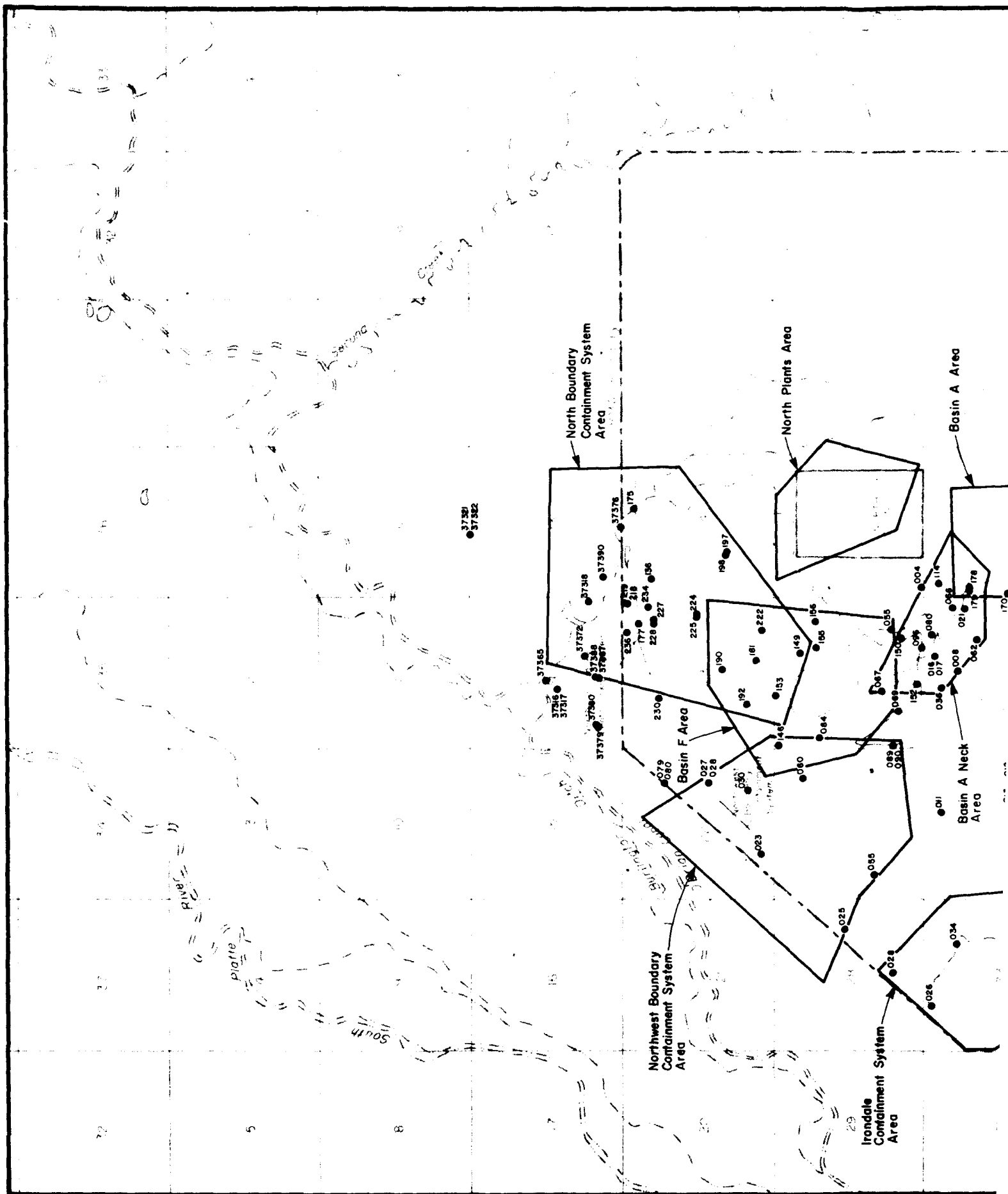
Prepared for:

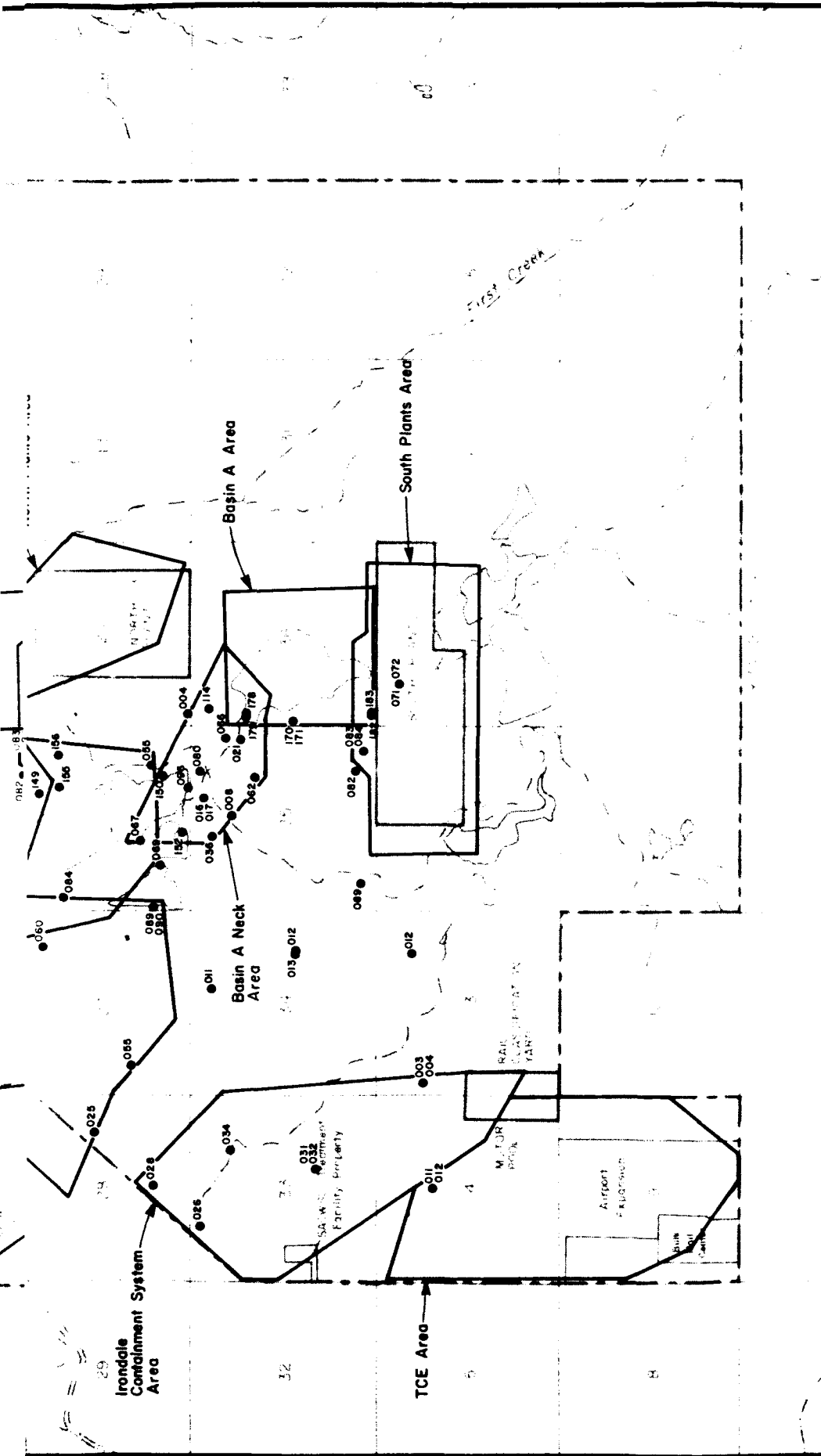
Program Manager's Office for
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FIGURE 4.3-3

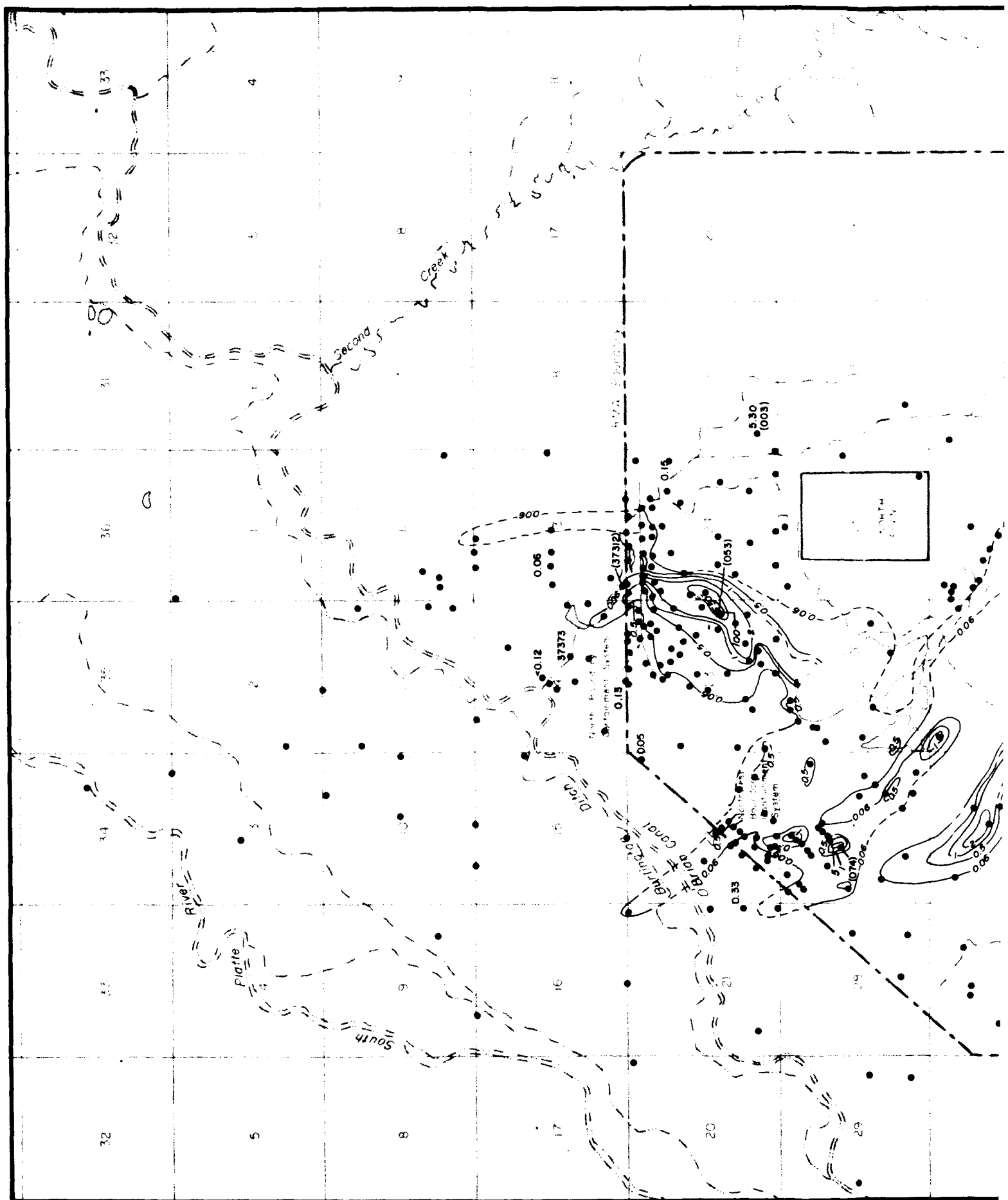
Spring 1988 Well Sampling Network Unconfined Ground-Water Flow System

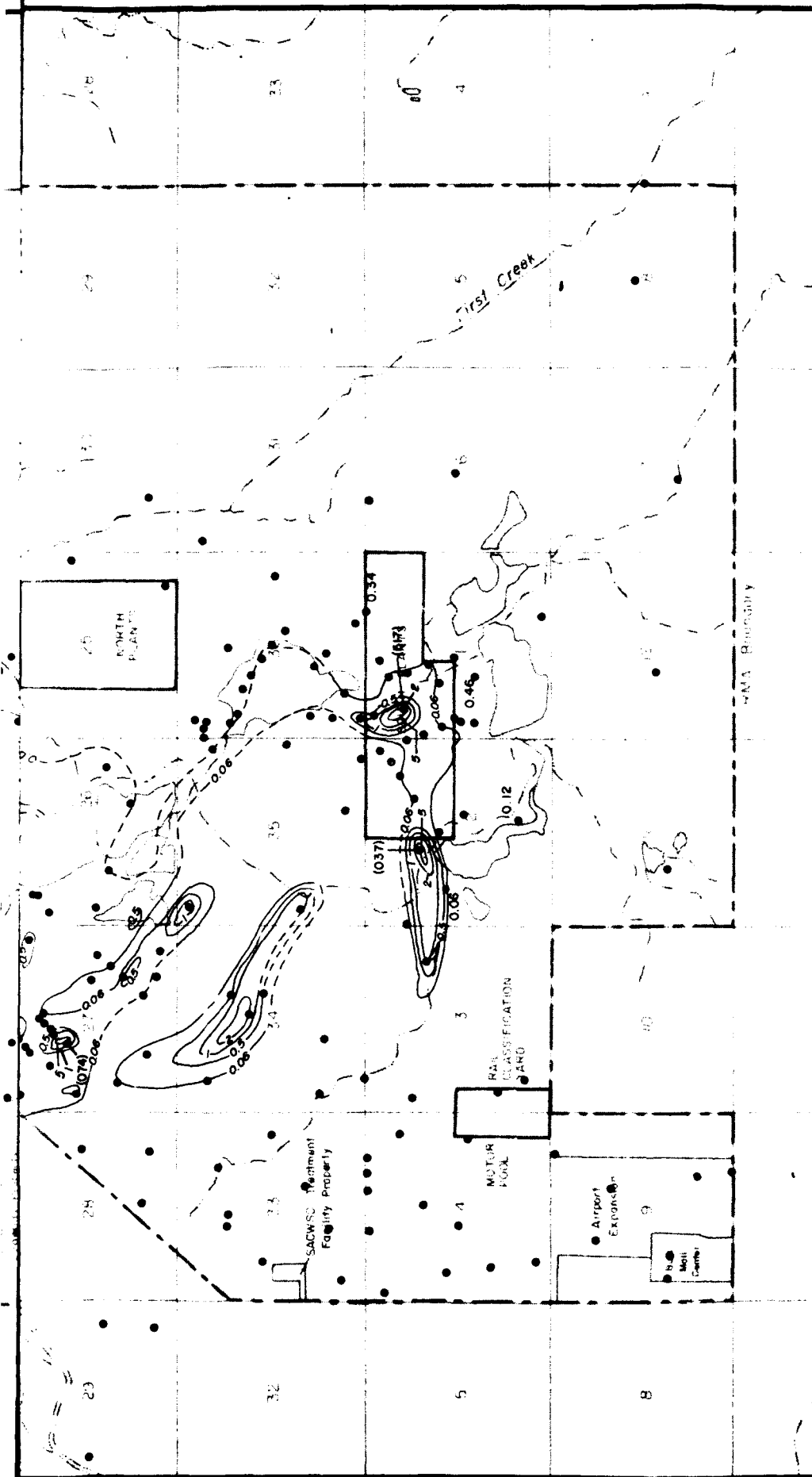
CMP Ground - Water Monitoring Annual Report
Prepared by: R.L. Stollar & Associates Inc.
Harding Lawson Associates





<p>Prepared for:</p> <p>Program Manager's Office for Rocky Mountain Arsenal Aberdeen Proving Ground, Maryland</p>	<p>FIGURE 4.3-4</p> <p>Spring 1988 Well Sampling Network</p> <p>Denver Formation Ground-Water Flow System</p> <p>CMP Ground - Water Monitoring Annual Report Prepared by: R.L. Stollar & Associates Inc. Harding Lawson Associates</p>
<p><u>Explanation</u></p> <p>● Denver Formation Well Location and Well Identification Number</p>	<p>North Arrow</p> <p>Scale: 0 to 8000 Feet / 0 to 2000 Meters</p>





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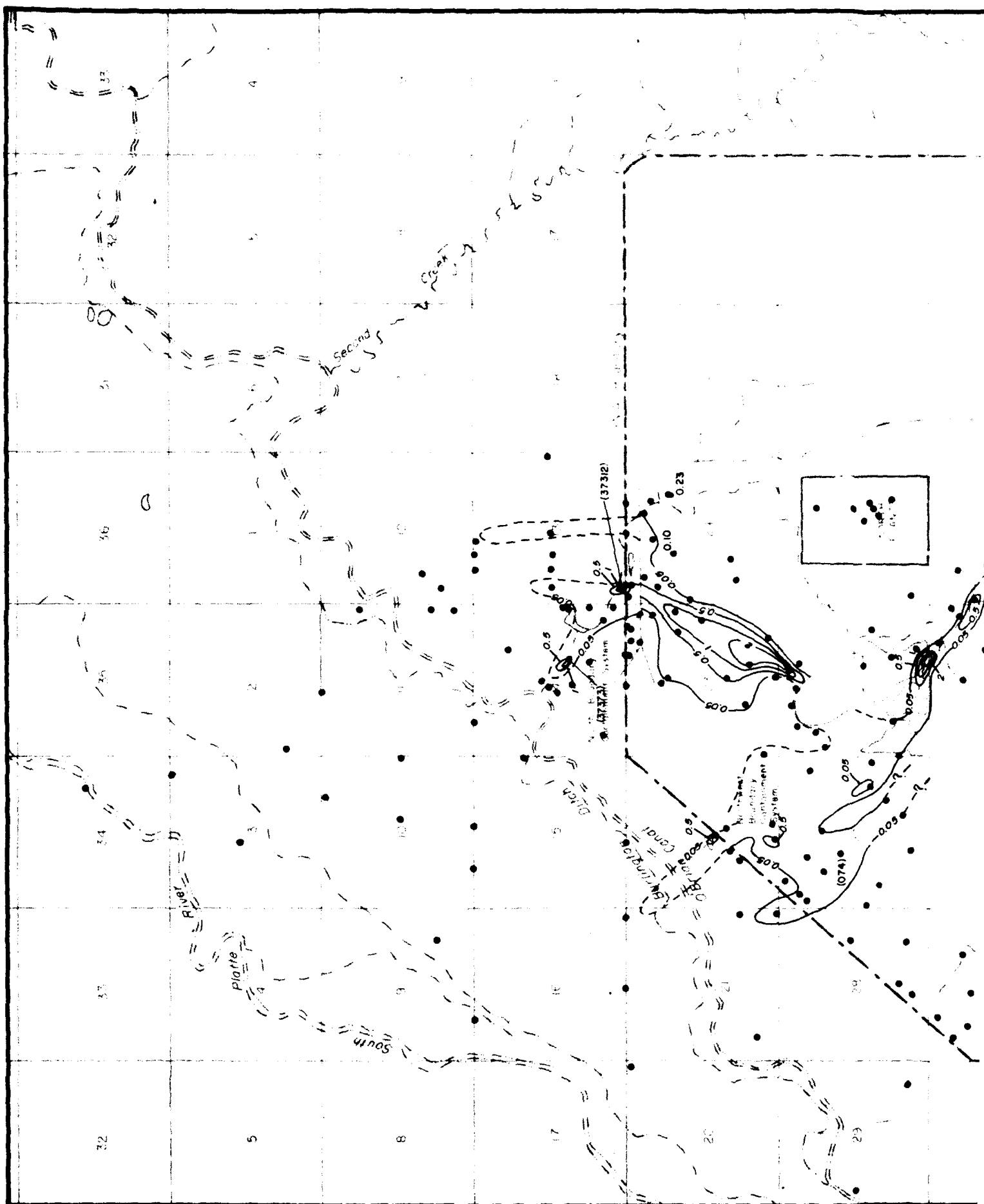
FIGURE 4.3-6
Dieldrin Plumes
Unconfined Ground-Water Flow System
Winter 1987/88
CMP Ground-Water Monitoring Annual Report
Prepared by: R.L. Stollar & Associates Inc.
Harding Lawson Associates

Explanation

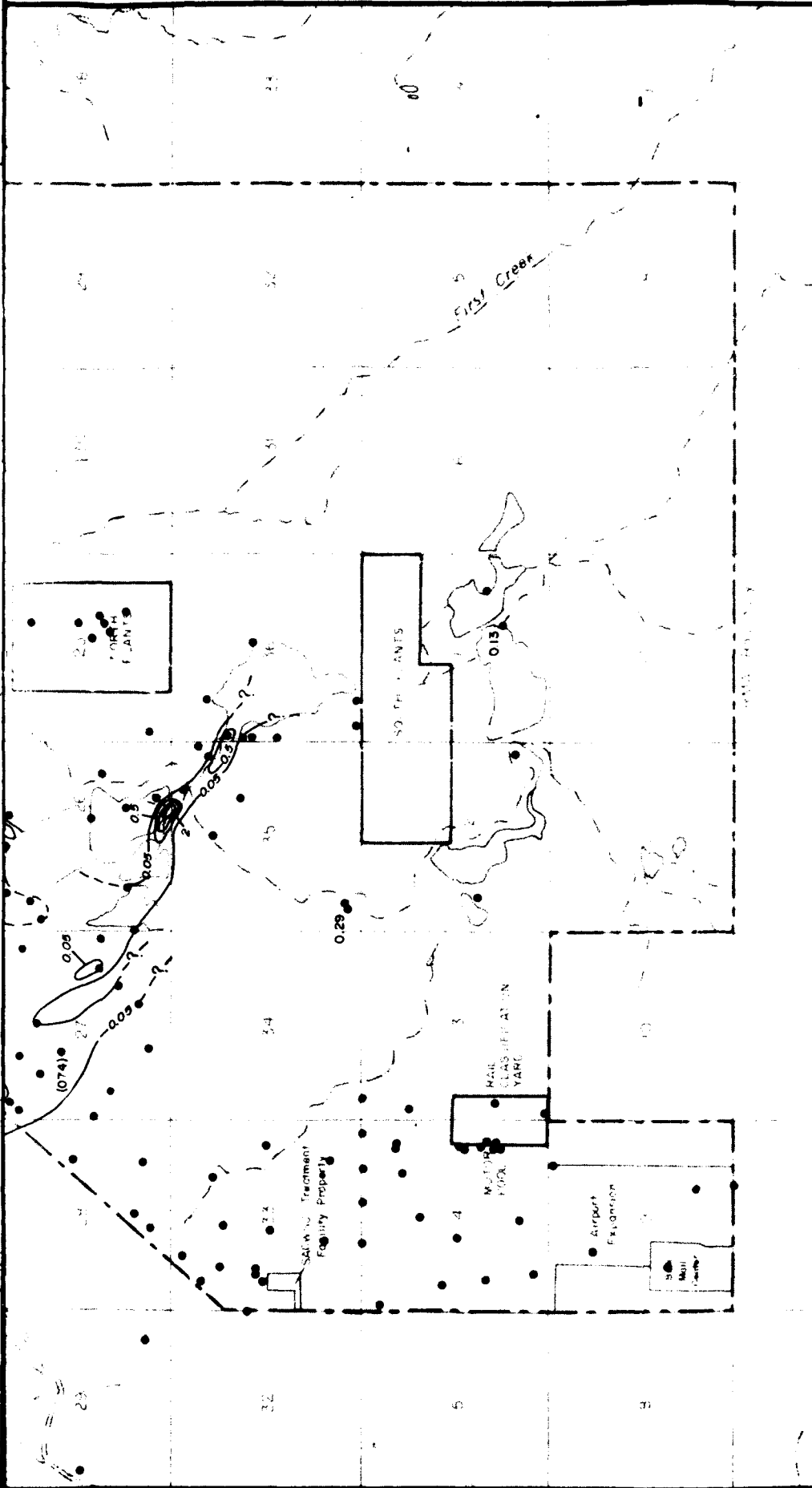
- Isoconcentration Line, Dashed where Inferred
- Isolated Detection or Concentration less than Highest CRL, in $\mu\text{g/l}$ (Well Identification Number)

Isoconcentration Values ($\mu\text{g/l}$)

0.06
0.50
1
2
5
50
100



①



Explanation

- Isoconcentration Line, Dashed where Inferred
- 0.23 Isolated Detection or Concentration less than Highest CRL, in $\mu\text{g/l}$ (Well Identification Number)
- (---) Extent of Plume not Fully Evaluated During Semi-Annual Specific Area Monitoring

Isoconcentration Values ($\mu\text{g/l}$)

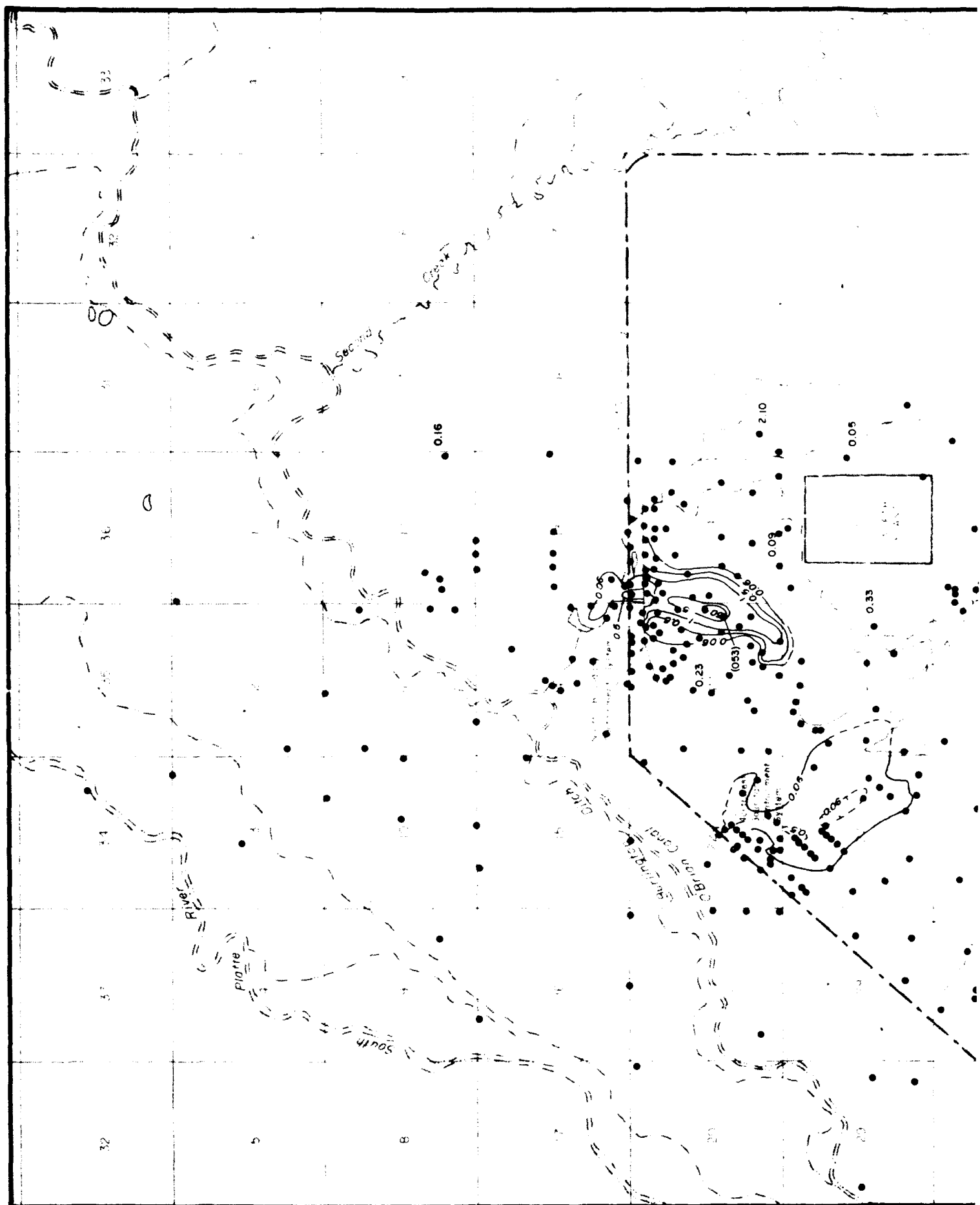
0.05
0.5
1
2
5

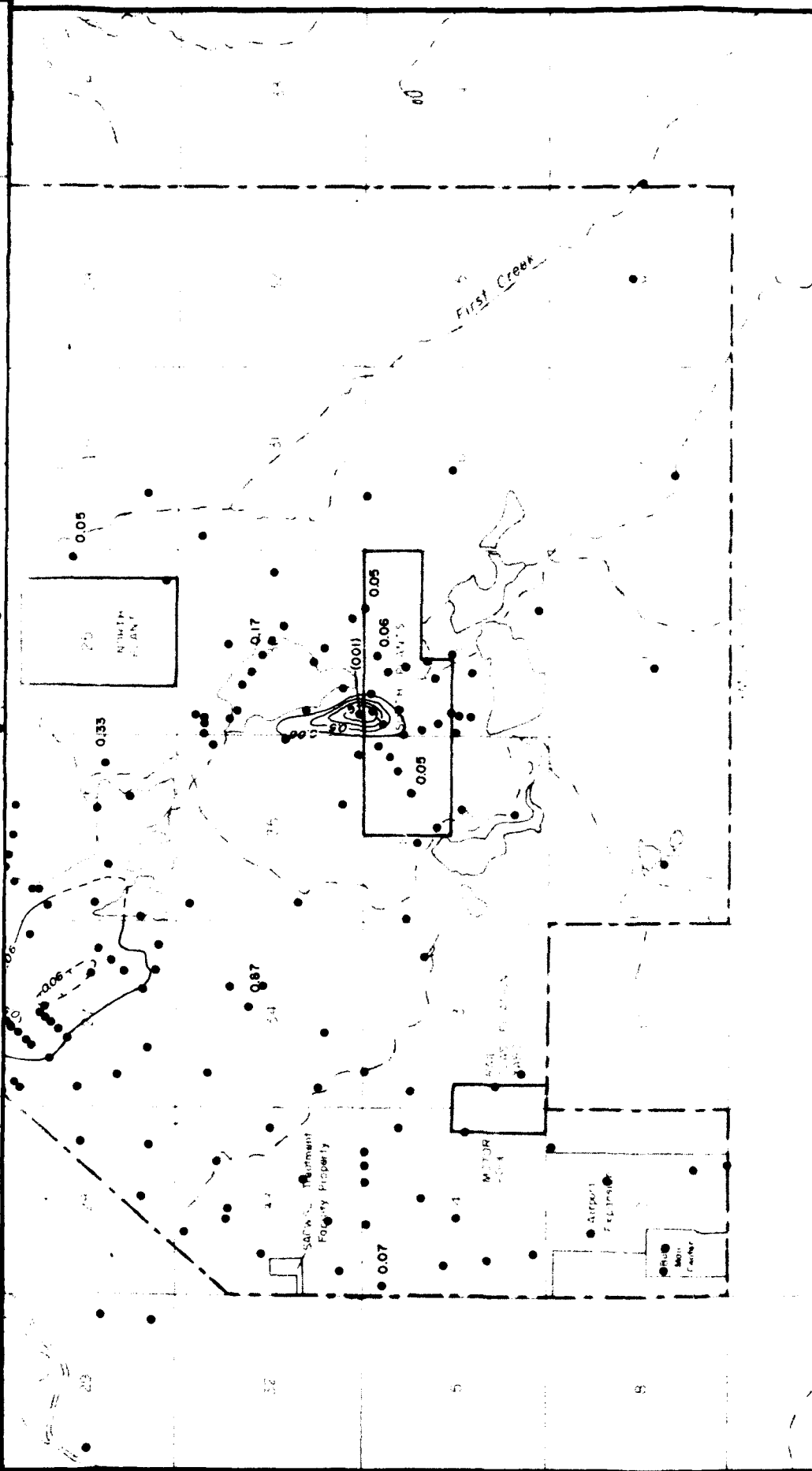
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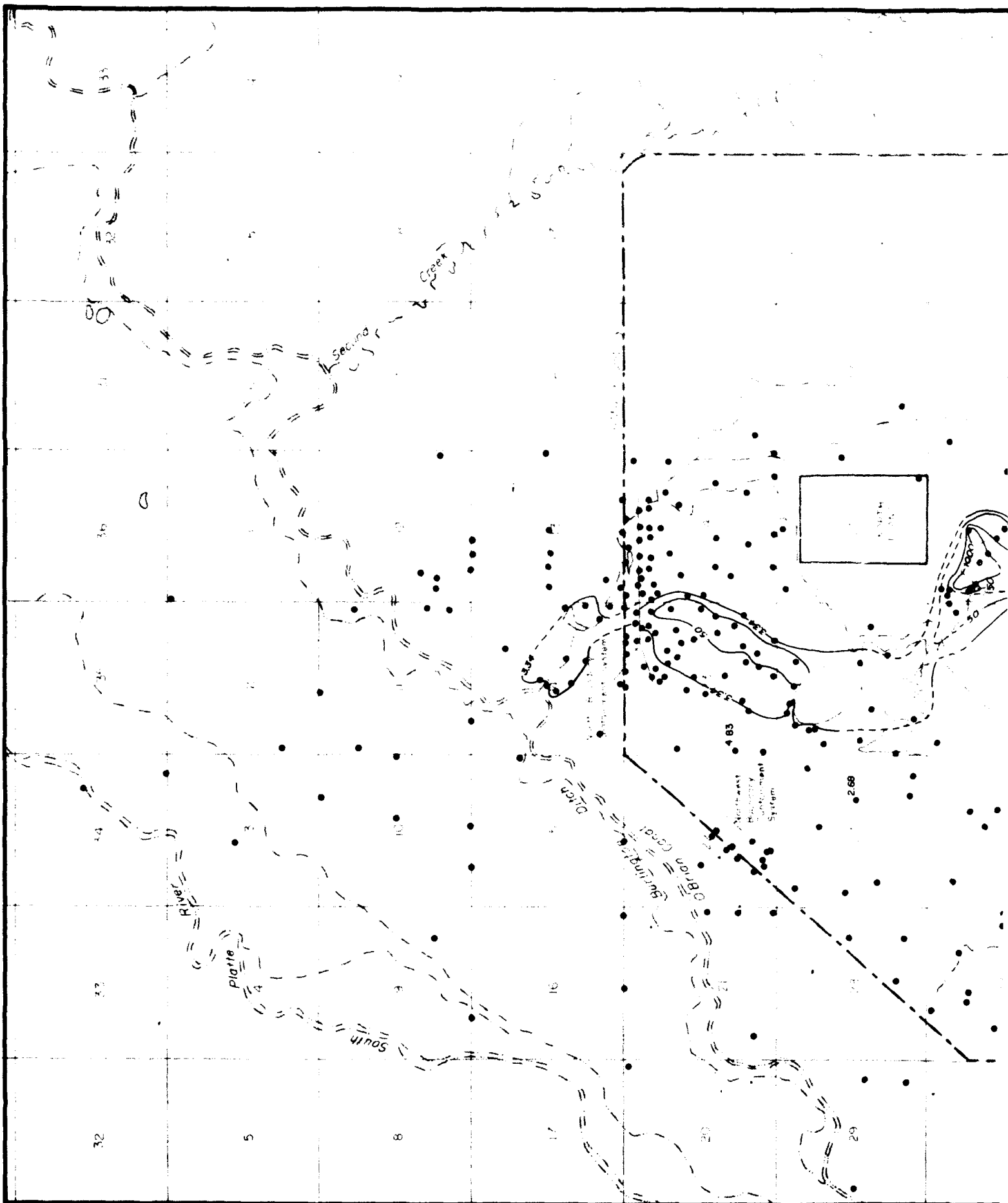
FIGURE 4.3-7

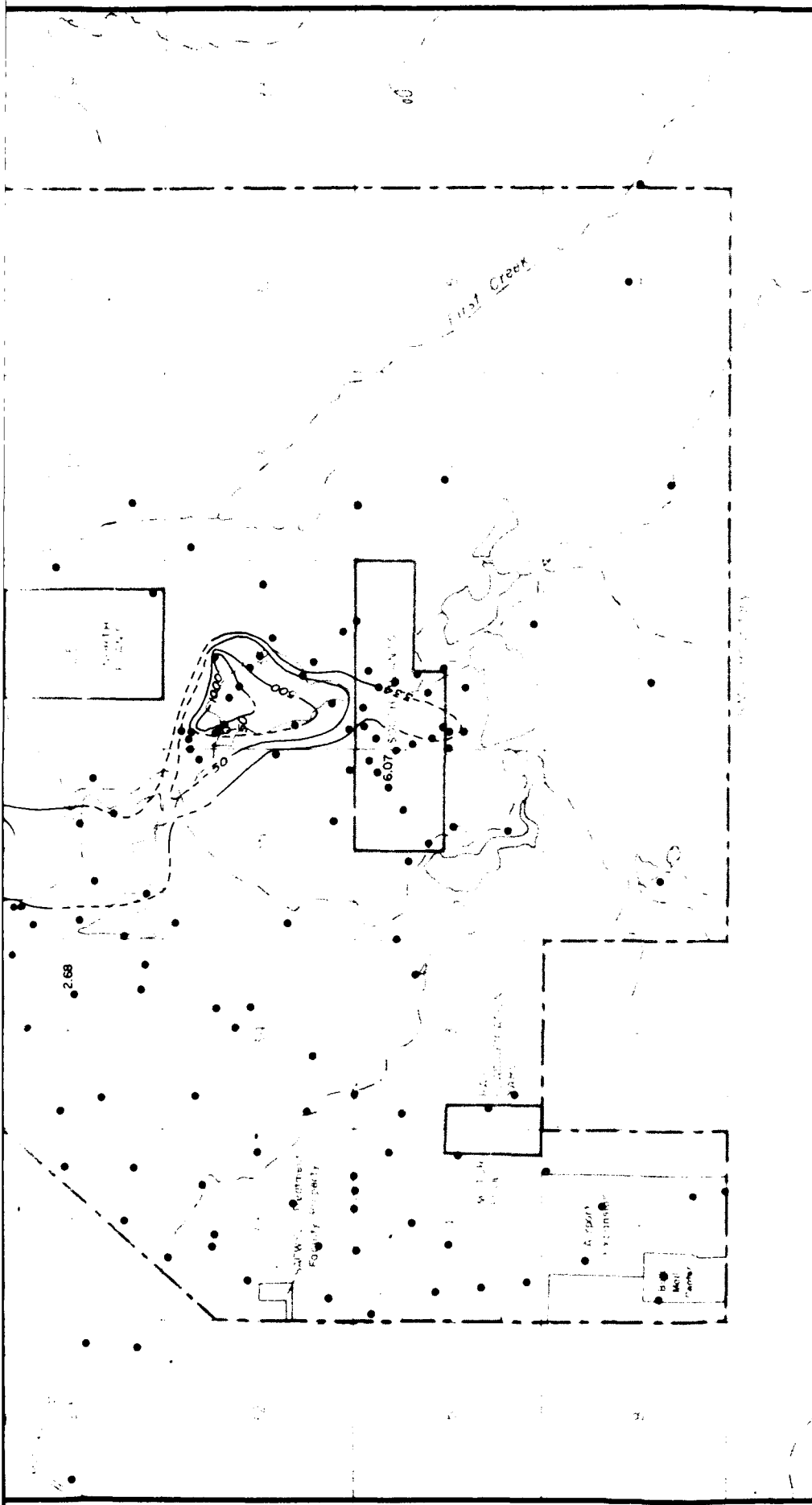
Dieldrin Plumes
Unconfined Ground-Water Flow System
Spring 1988
CMP Ground-Water Monitoring Annual Report
Prepared by: R.L. Stollar & Associates Inc.
Harding Lawson Associates





<p>Prepared for:</p> <p>Program Manager's Office for Rocky Mountain Arsenal Aberdeen Proving Ground, Maryland</p>	<p>FIGURE 4.3-8 Endrin Plumes Unconfined Ground-Water Flow System Winter 1987/88</p> <p>CMP Ground-Water Monitoring Annual Report Prepared by: R.L. Stollar & Associates Inc. Harding Lawson Associates</p>
<p>Explanation</p> <p>--- Isoconcentration Line, Dashed where Inferred</p> <p>••• Isolated Detection or Concentration less than Highest CRL, in $\mu\text{g/l}$ (Well Identification Number)</p> <p>Isoconcentration Values ($\mu\text{g/l}$)</p> <p>0.06 0.5 1 5 50</p>	<p>0 4000 8000 Feet</p> <p>0 1000 2000 Meters</p>





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FIGURE 4.3-9

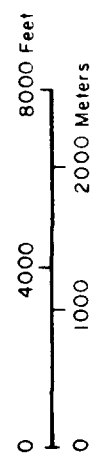
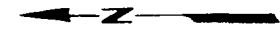
Dithiane/Oxathiane Plumes
Unconfined Ground-Water Flow System
Winter 1987/88
CMP Ground - Water Monitoring Annual Report
Prepared by: R.L. Stollar & Associates Inc.
Harding Lawson Associates

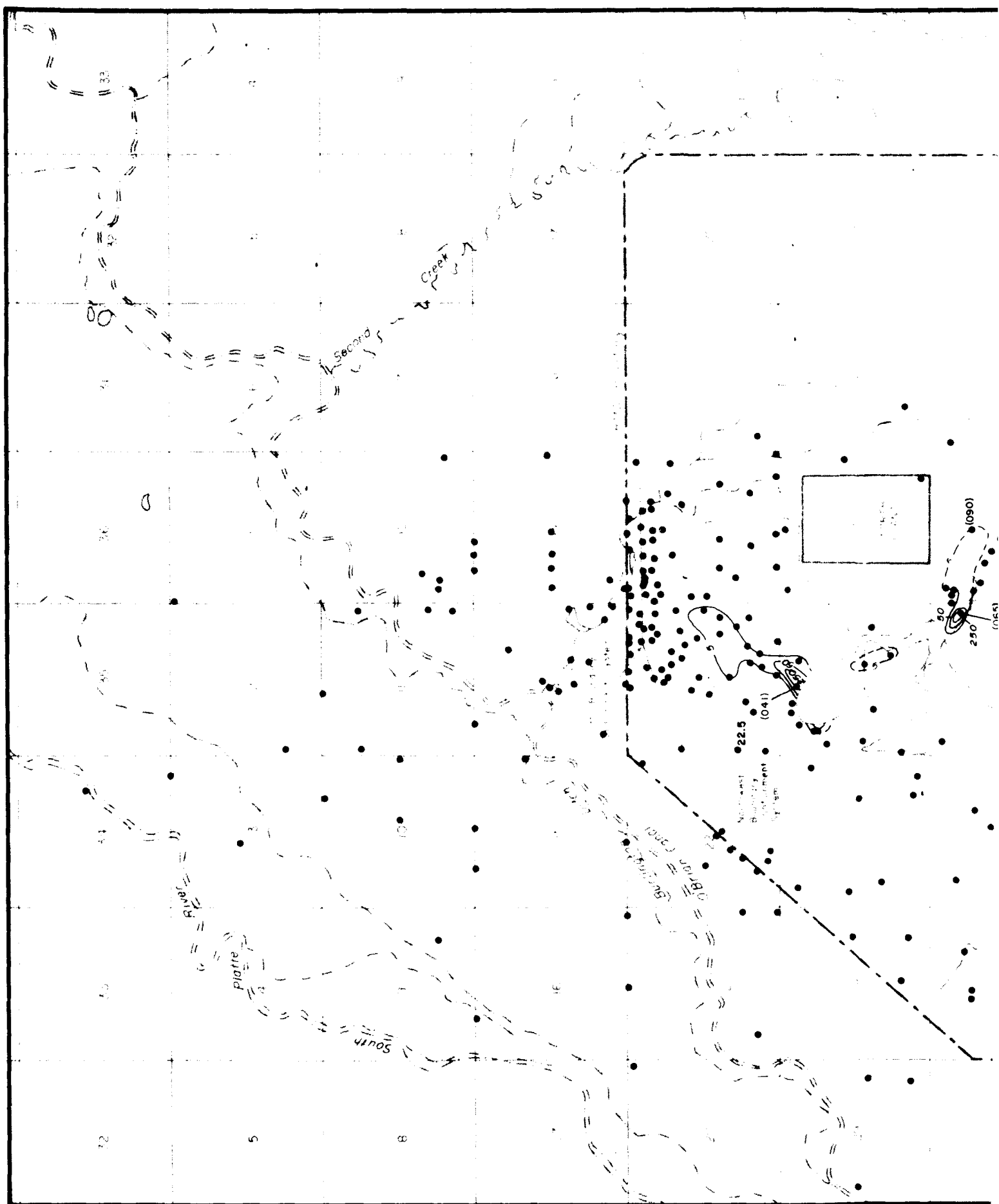
Explanation

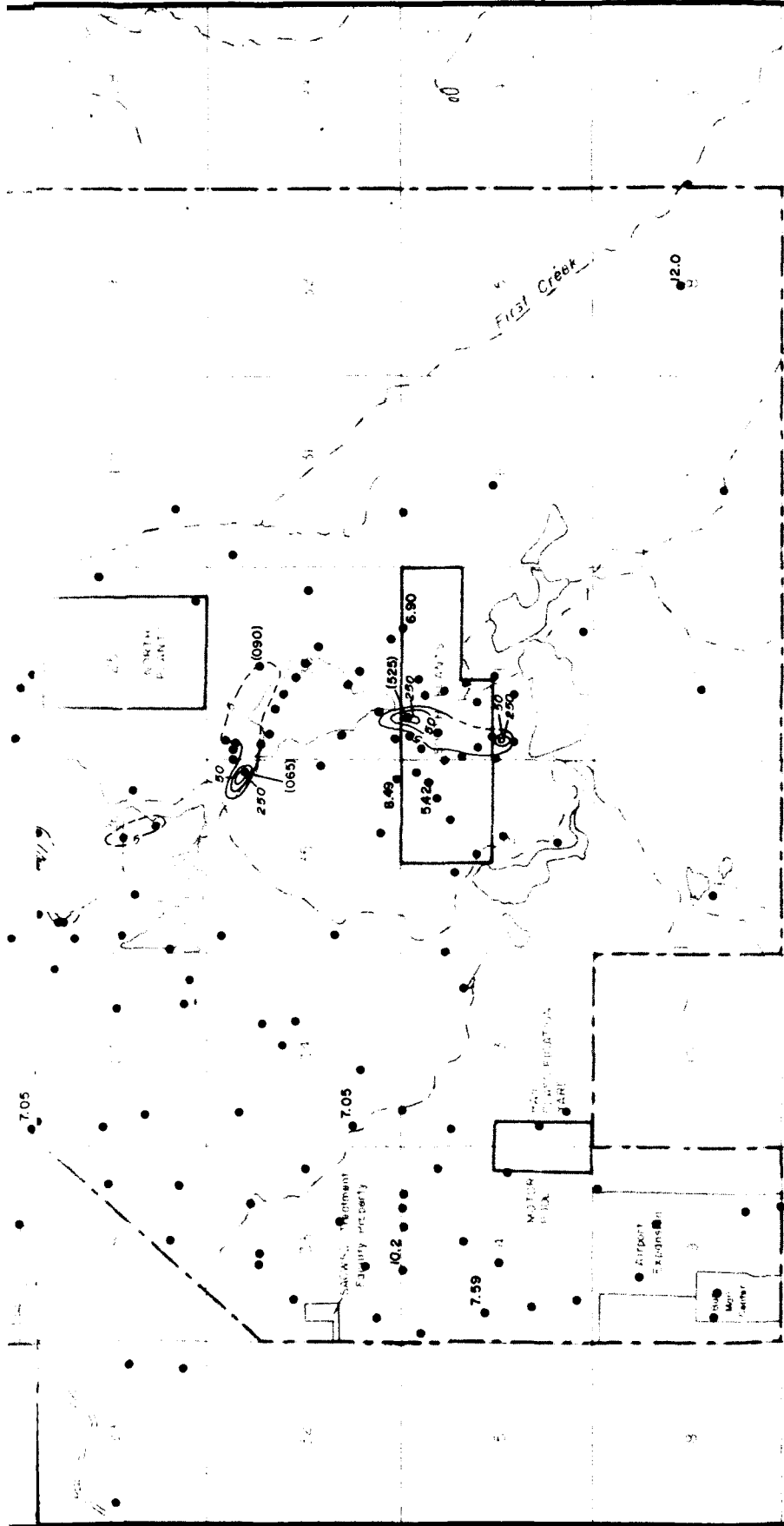
- Isoconcentration Line, Dashed where Inferred
- 6.07 Isolated Detection or Concentration Less than Highest CRL, in ug/l

Isoconcentration Value (ug/l)

- 3.34
- 50
- 500
- 1000







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FIGURE 4.3-10

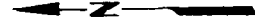
Benzo-thiazole Plumes
Unconfined Ground-Water Flow System
Winter 1987/88
CMP Ground-Water Monitoring Annual Report
Prepared by: R.L. Stollar & Associates Inc.
Harding Lawson Associates

Explanation

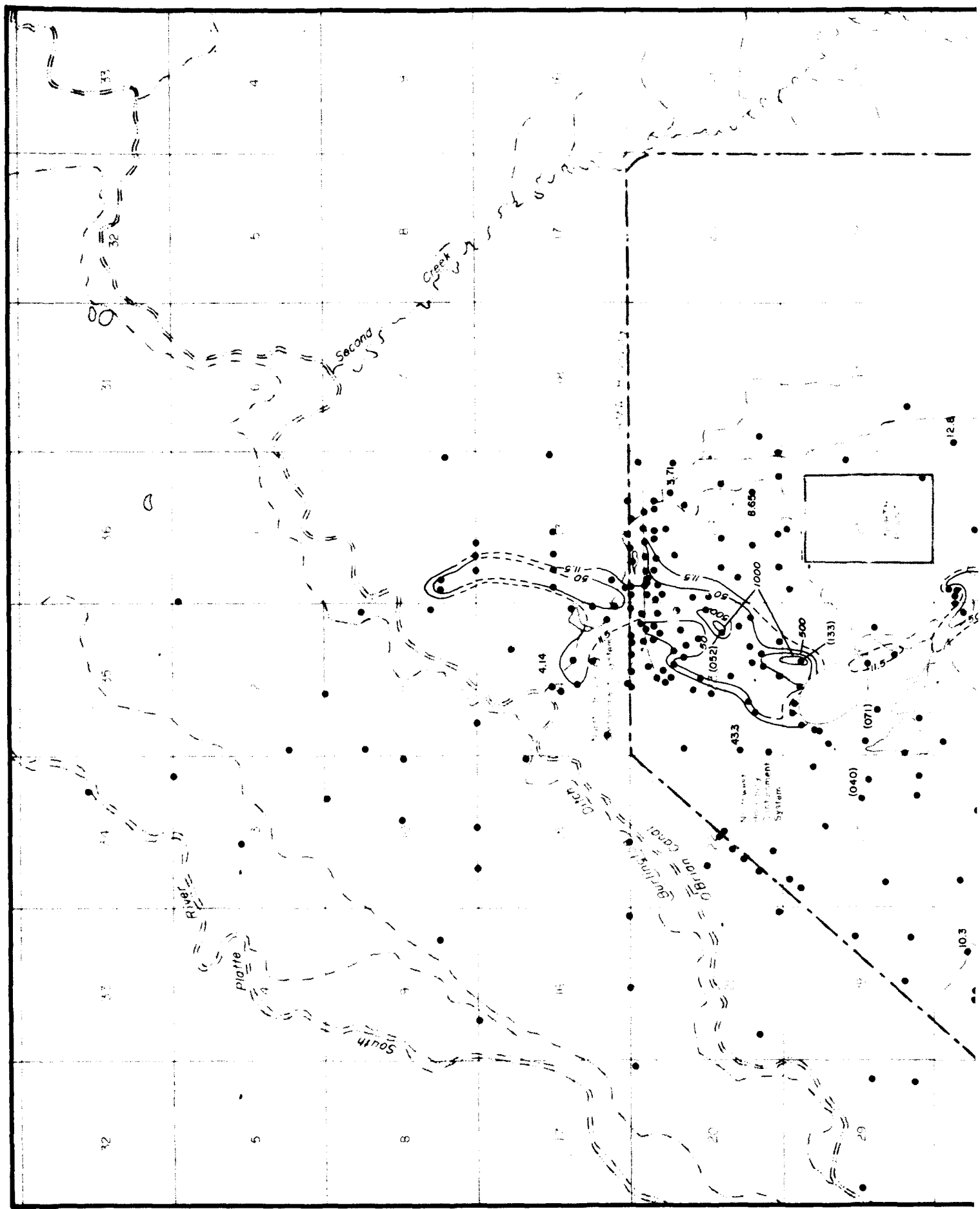
- Isoconcentration Line, Dashed where Inferred
- Isolated Detection or Concentration less than Highest CRL, in $\mu\text{g/l}$ (Well Identification Number)

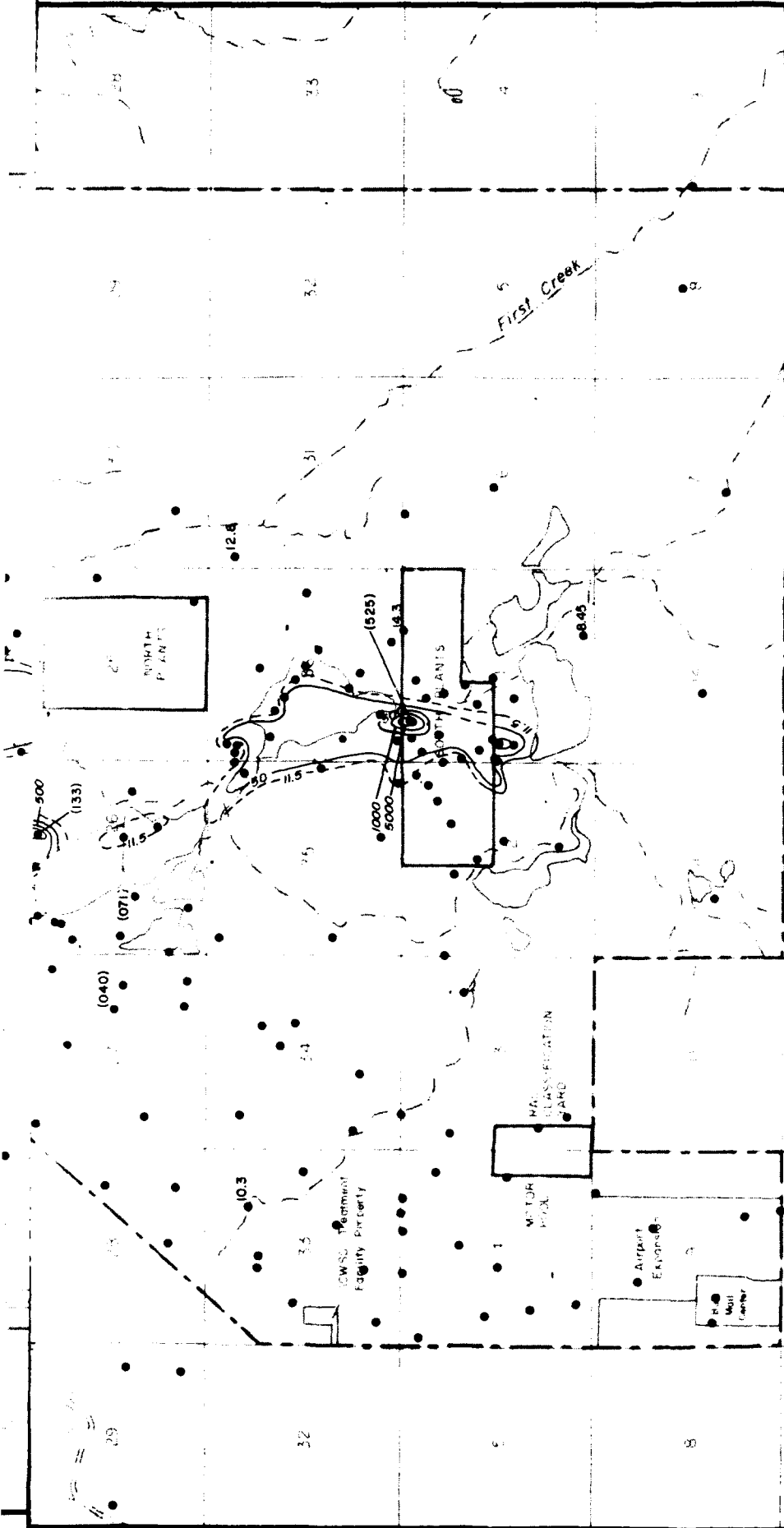
Isoconcentration Values ($\mu\text{g/l}$)

5
50
250



0 4000 8000 Feet
0 1000 2000 Meters

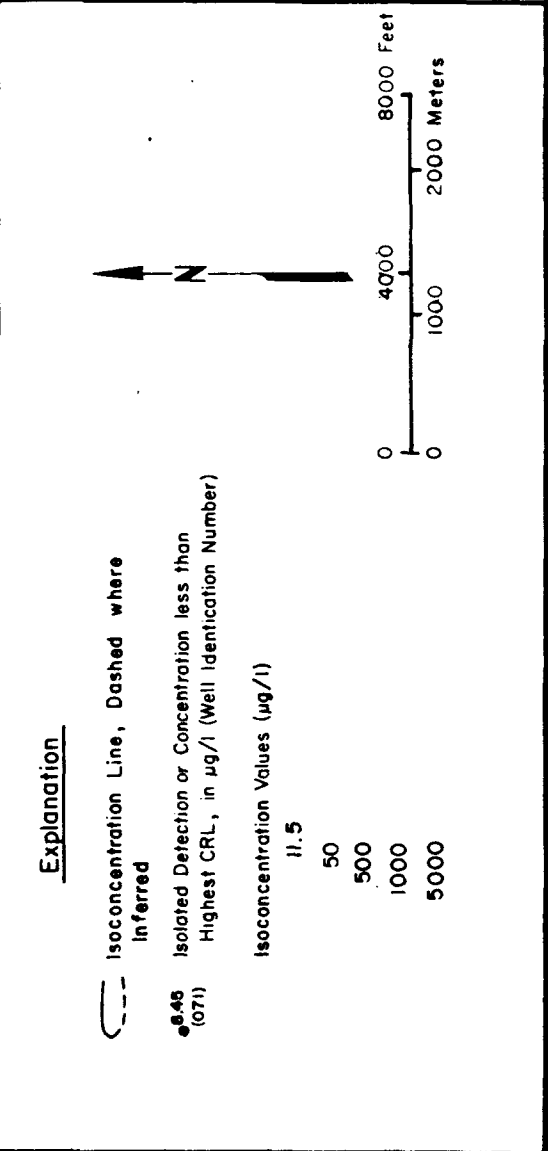


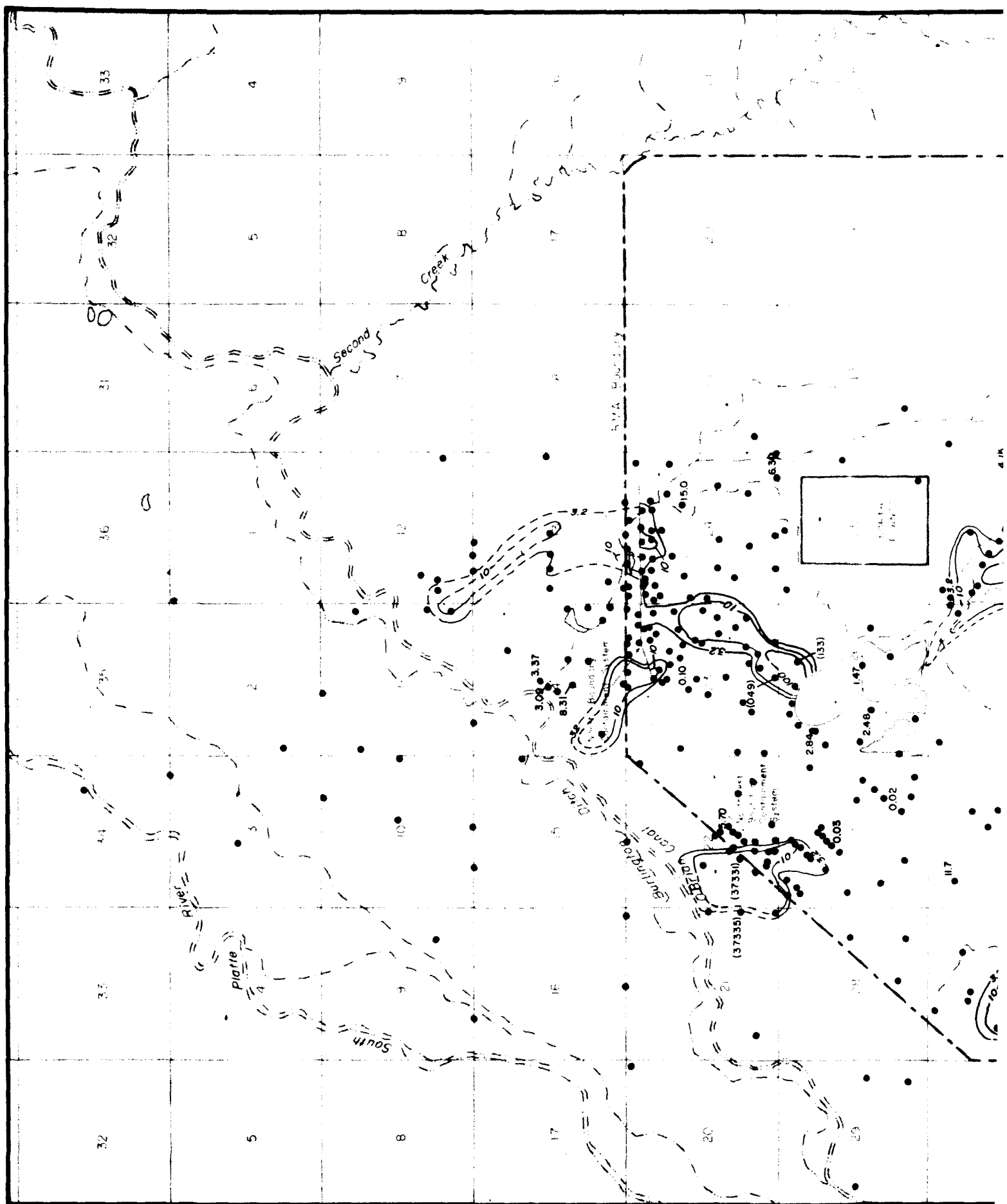


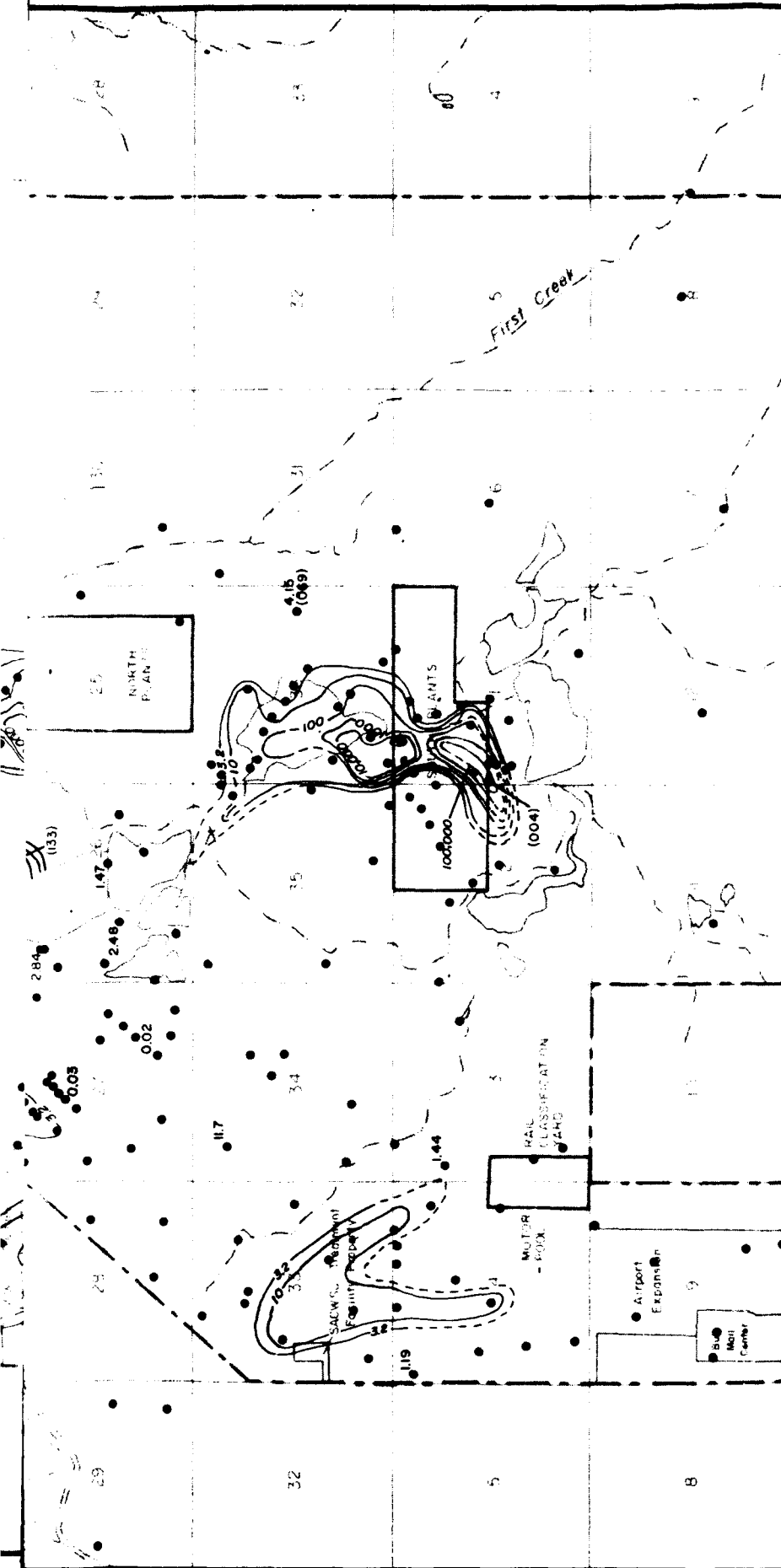
Compounds included in this group are:
 Chlorophenylmethyl sulfide
 Chlorophenylmethyl sulfone
 Chlorophenylmethyl sulfoxide

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FIGURE 4.3-II
 Summed Organosulfur Compound Plumes
 Unconfined Ground-Water Flow System
 Winter 1987/88
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Compounds included in this group are:
 Benzene
 Chlorobenzene
 Toluene
 Ethylbenzene
 m-Xylene
 o,p-Xylene

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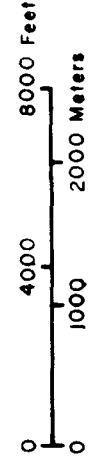
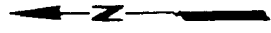
FIGURE 4.3-12
 Summed Volatile Aromatic Compound Plumes
 Unconfined Ground-Water Flow System -
 Winter 1987/88
 CMP Ground-Water Monitoring Annual Report
 Prepared by: R.L. Stollar & Associates Inc.
 Harding Lawson Associates

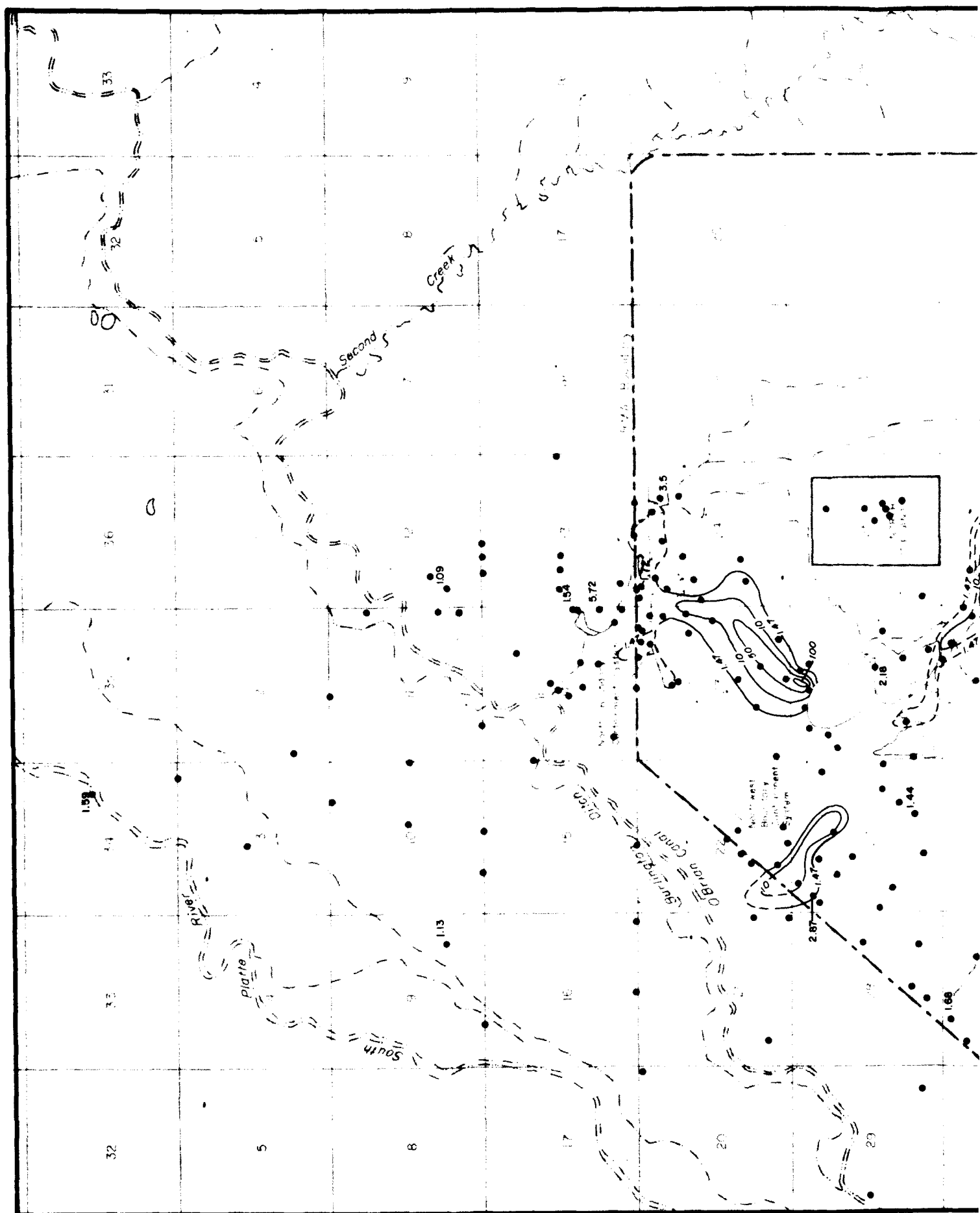
Explanation

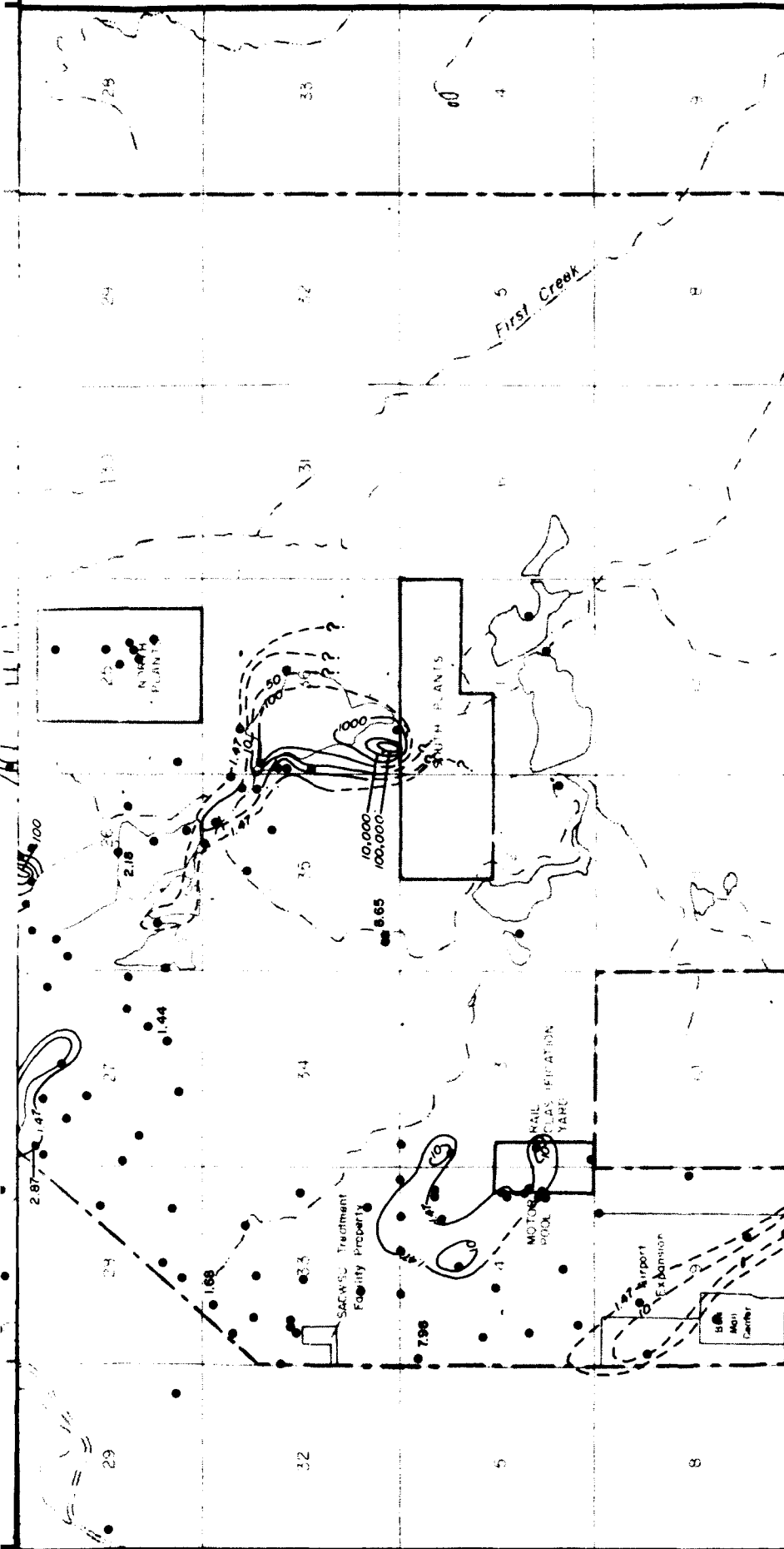
- Isoconcentration Line, Dashed where Inferred
- Isolated Detection or Concentration less than Highest CRL, in µg/l (Well Identification Number)

Isoconcentration Values (µg/l)

- 3.2
- 10
- 100
- 1000
- 10,000
- 100,000







Compounds included in this group are:

Benzene	Ethylbenzene
Chlorobenzene	m-Xylene
Toluene	o,p-Xylene

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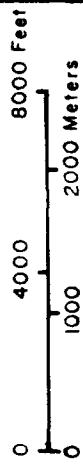
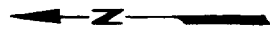
FIGURE 4.3-13
Summed Volatile Aromatic Compound Plumes
Unconfined Ground-Water Flow System
Spring 1988
CMP Ground - Water Monitoring Annual Report
Prepared by: R.L. Stollar & Associates Inc.
Harding Lawson Associates

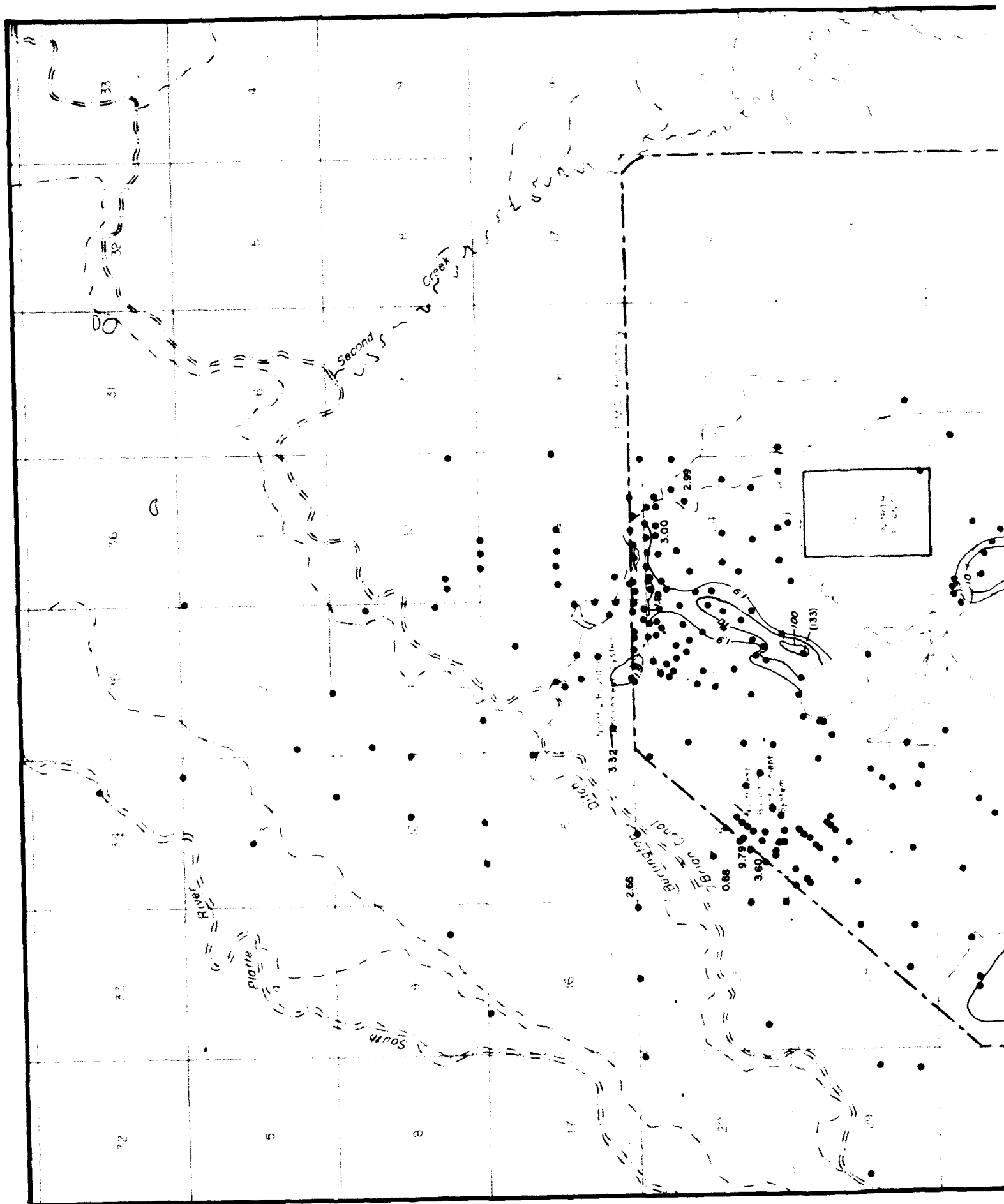
Explanation

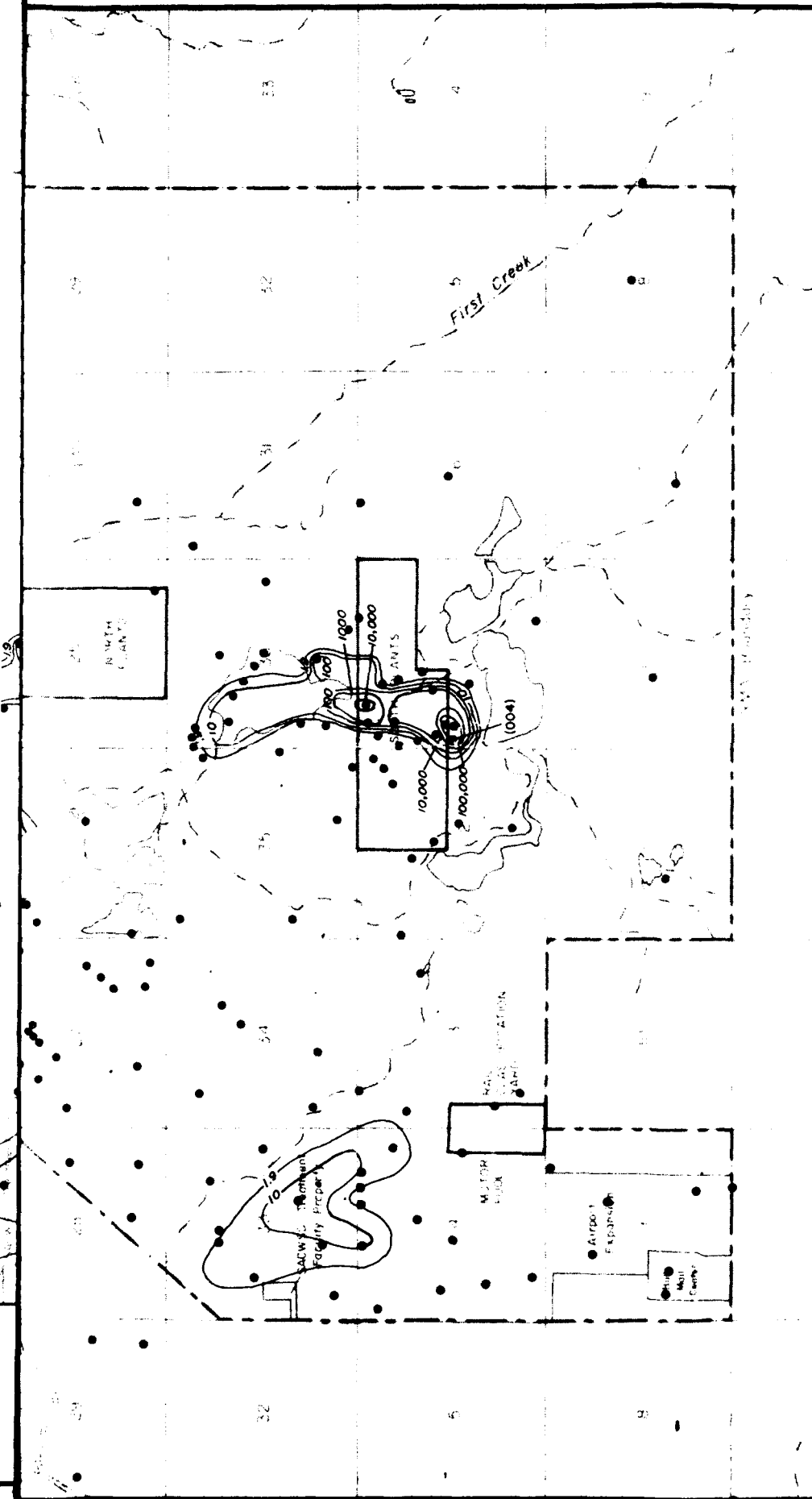
- Isoconcentration Line, Dashed where Inferred
- Isolated Detection or Concentration less than Highest CRL, in $\mu\text{g/l}$
- - - Extent of Plume not Fully Evaluated During Semi-Annual Specific Area Monitoring

Isoconcentration Values ($\mu\text{g/l}$)

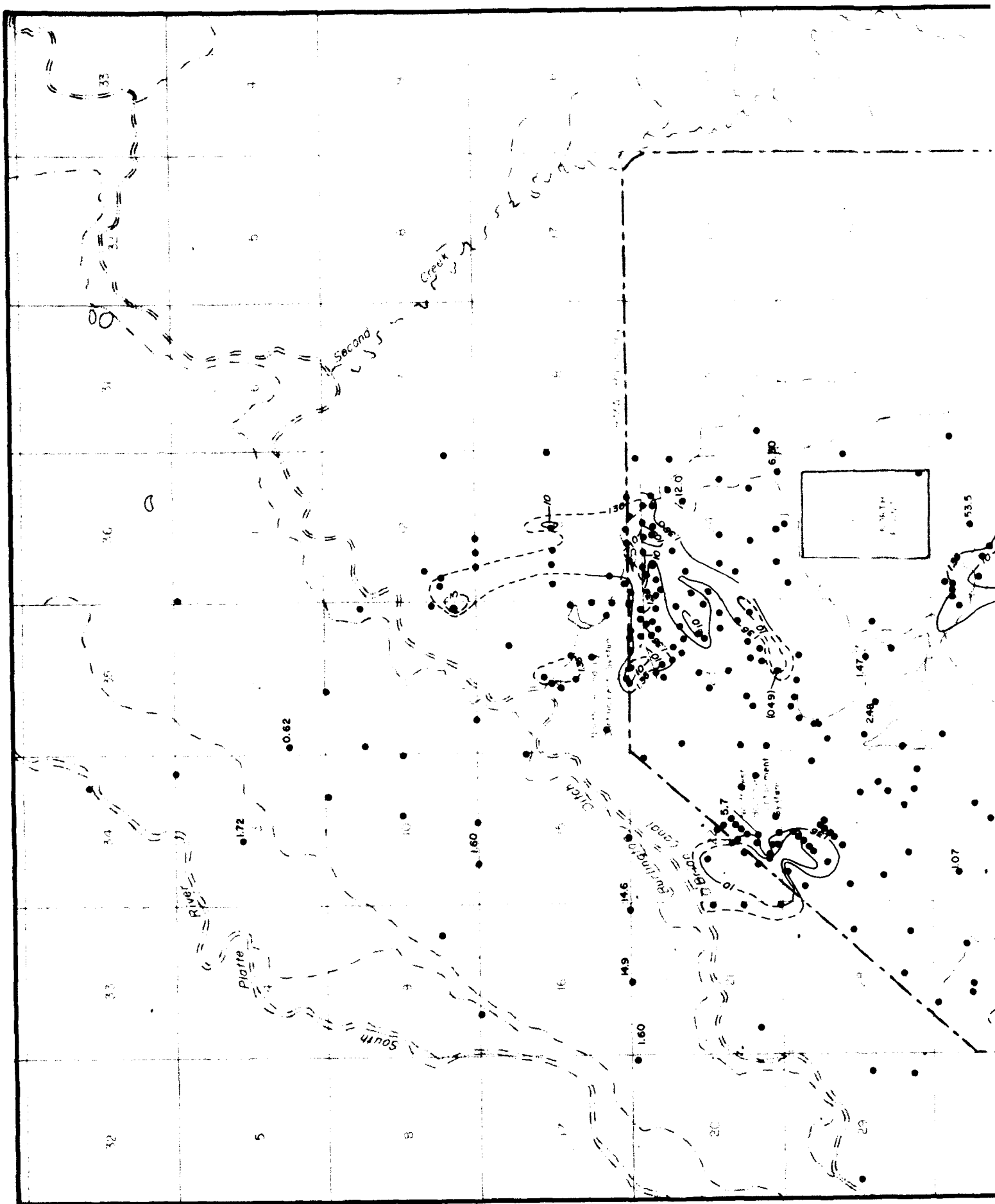
- 1.47
- 10
- 50
- 100
- 1000
- 10,000
- 100,000

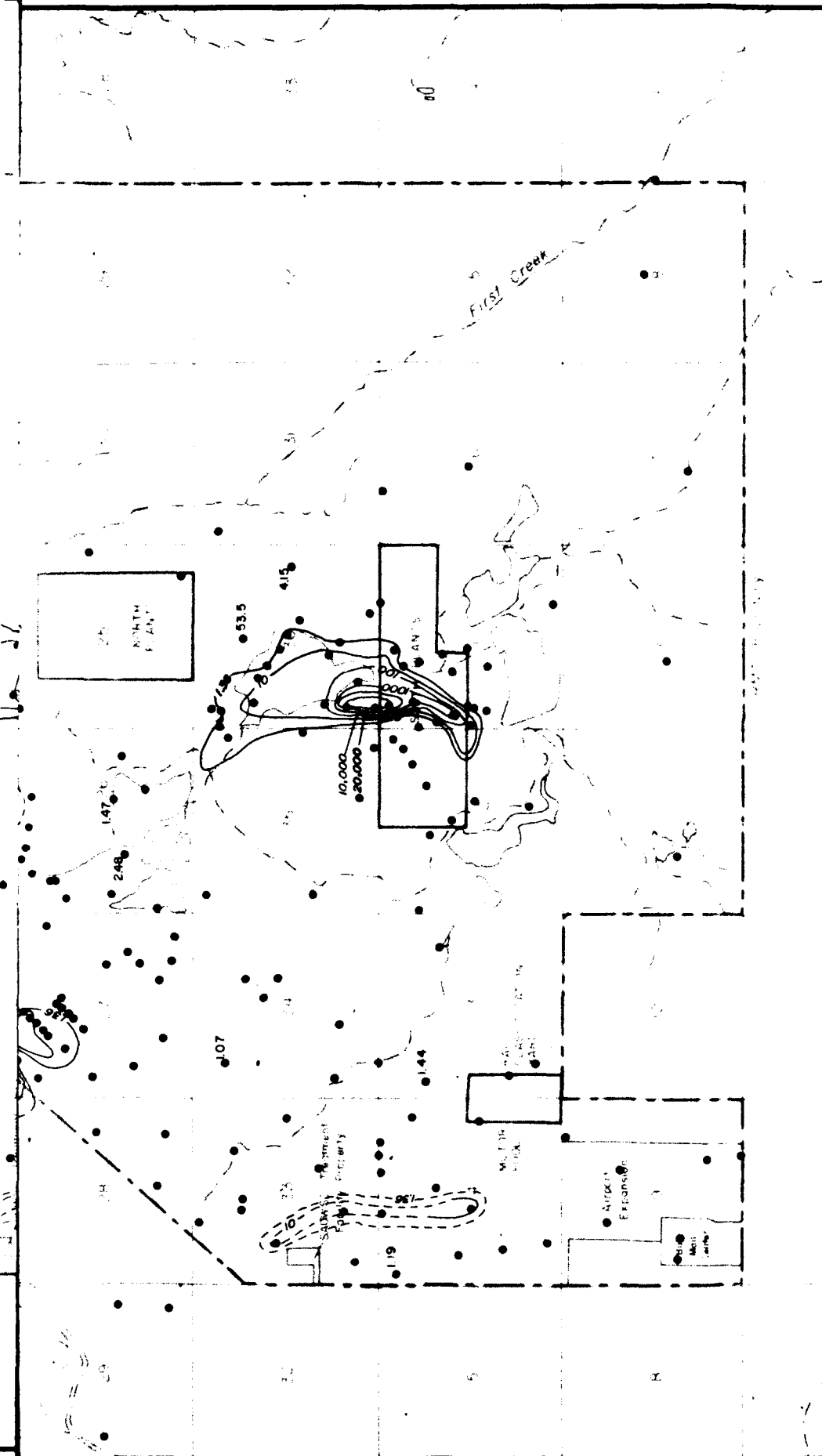






<p>Prepared for:</p> <p>Program Manager's Office for Rocky Mountain Arsenal Aberdeen Proving Ground, Maryland</p>	<p>FIGURE 4.3-14</p> <p>Benzene Plumes Unconfined Ground-Water Flow System - Winter 1987/88 CMP Ground - Water Monitoring Annual Report Prepared by: R.L. Stollar & Associates Inc. Harding Lawson Associates</p>
<p>Explanation</p> <p>— Isoconcentration Line, Dashed where Inferred</p> <p>● Isolated Detection or Concentration less than Highest CRL, in $\mu\text{g/l}$ (Well Identification Number)</p> <p>Isoconcentration Values ($\mu\text{g/l}$)</p> <p>1.9 10 100 1000 10,000 100,000</p>	<p>North Arrow</p> <p>Scale: 0 to 8000 Feet / 0 to 2000 Meters</p>





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FIGURE 4.3-15

Chlorobenzene Plumes
Unconfined Ground-Water Flow System
Winter 1987/88
CMP Ground-Water Monitoring Annual Report
Prepared by: R.L. Stollar & Associates Inc.
Harding Lawson Associates

Explanation

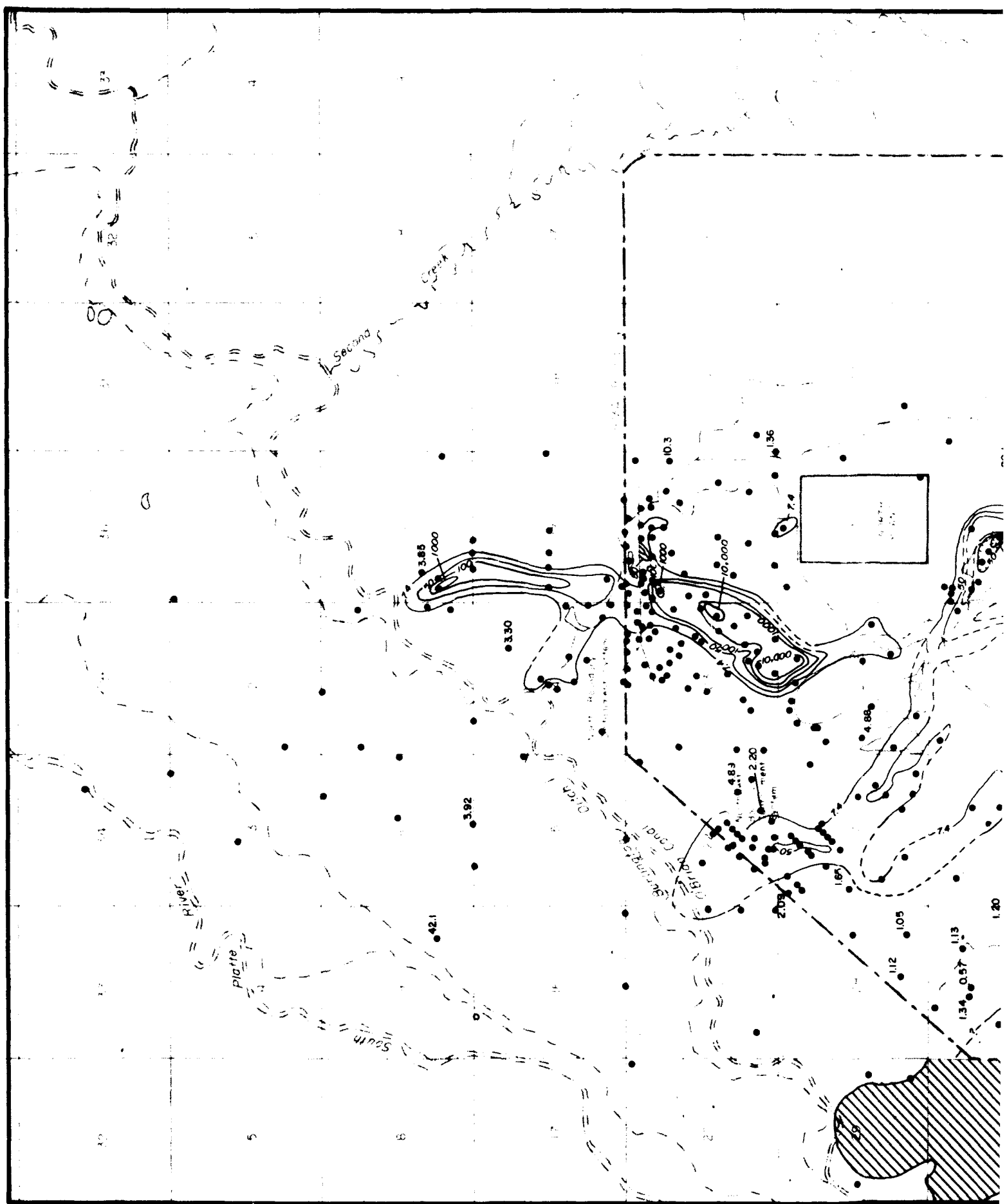
- Isococoncentration Line, Dashed where Inferred
- Isolated Detection or Concentration less than Highest CRL, in $\mu\text{g/l}$ (Well Identification Number)

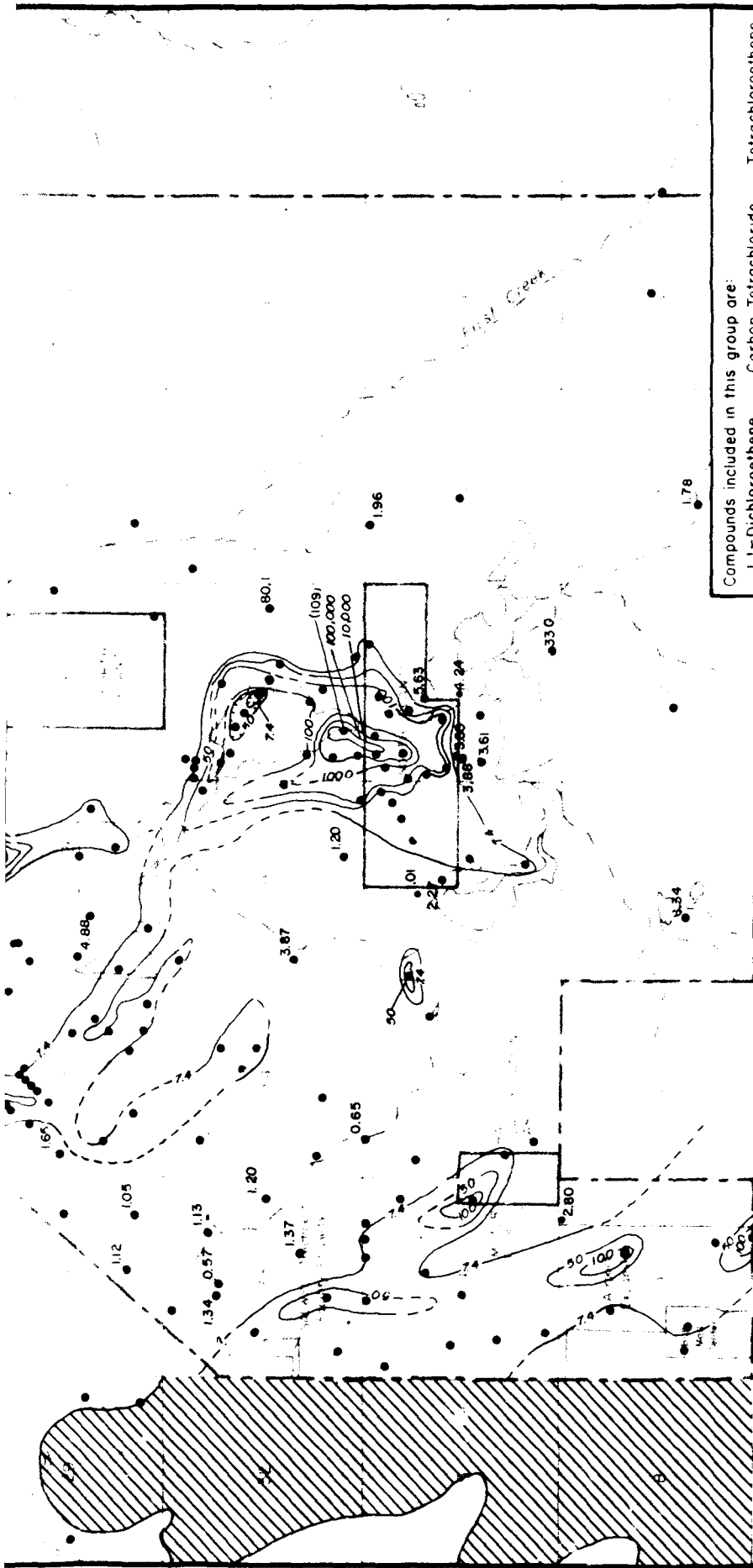
Isococoncentration Values ($\mu\text{g/l}$)

1.36
10
100
1000
10,000
20,000



0 4000 8000 Feet
0 1000 2000 Meters





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FIGURE 4.3-16

Summed Volatile Organohalogen Compound Plumes
Unconfined Ground-Water Flow System
Winter 1987/88

CMP Ground-Water Monitoring Annual Report
Prepared by: R.L. Stollar & Associates Inc.
Harding Lawson Associates

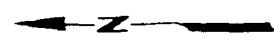
Explanation

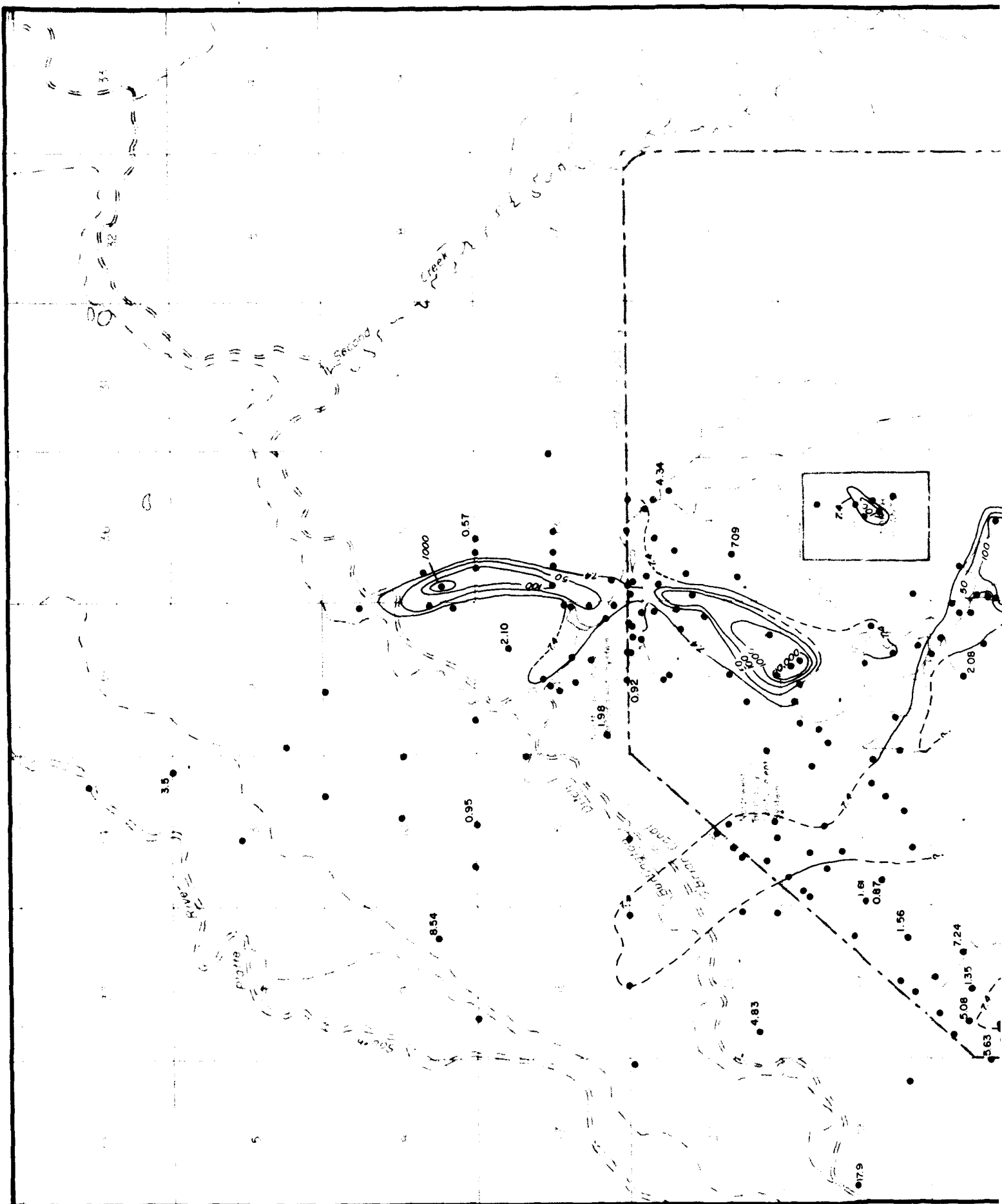
--- Isr concentration Line, Dashed where Inferred

● Isolated Detection or Concentration less than Highest CRL, in $\mu\text{g/l}$ (Well Identification Number)

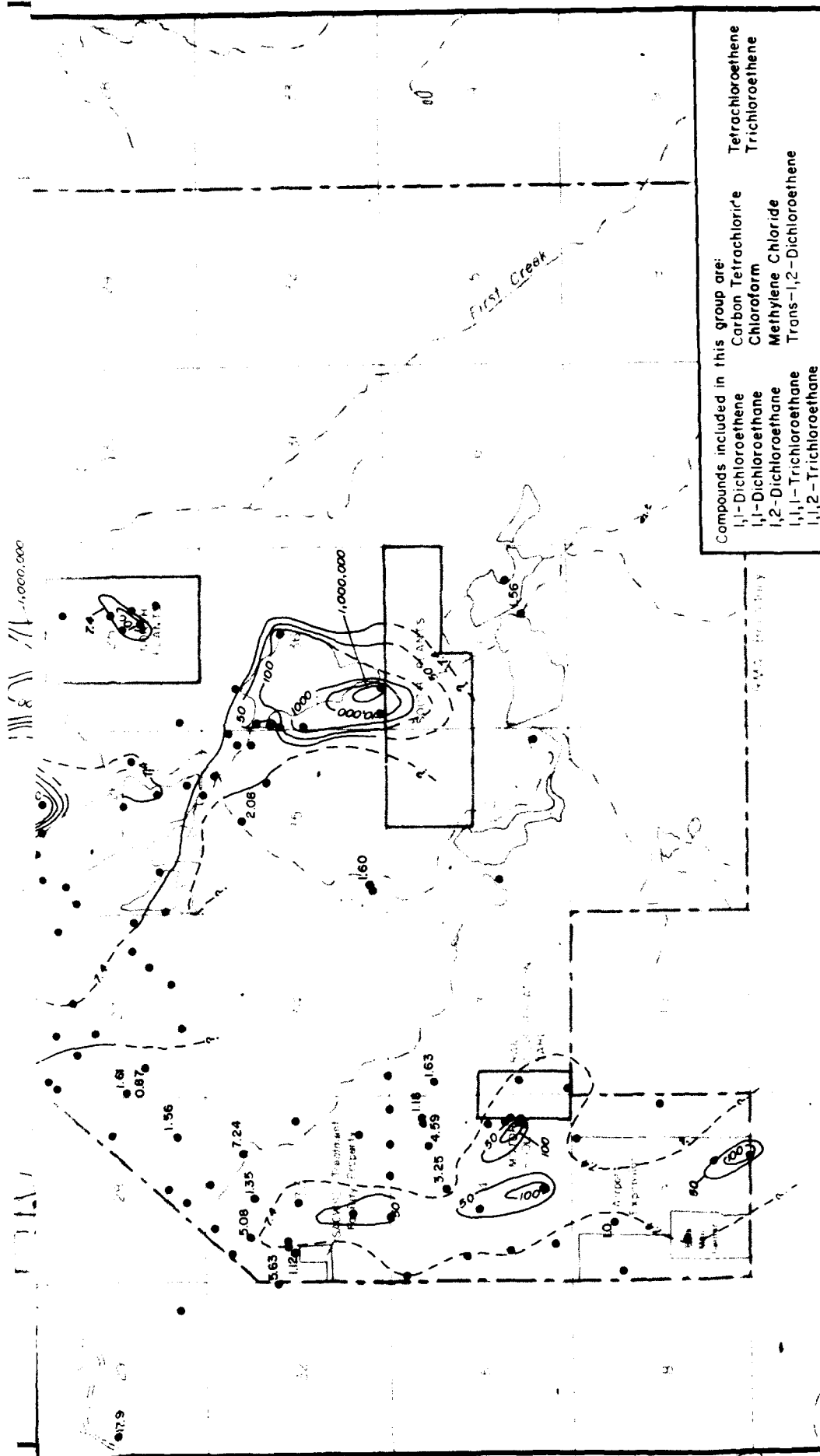
Isoconcentration Values ($\mu\text{g/l}$)

- 7.4
- 50
- 100
- 1000
- 10,000
- 100,000





1:10,000,000



Explanation

- Isoconcentration Line, Dashed where Inferred
- Isolated Detection or Concentration less than Highest CRL, in $\mu\text{g/l}$
- - - Extent of Plume not Fully Evaluated During Semi-Annual Specific Area Monitoring

Isoconcentration Values ($\mu\text{g/l}$)

- 7.4
- 50
- 100
- 1000
- 10,000
- 1,000,000

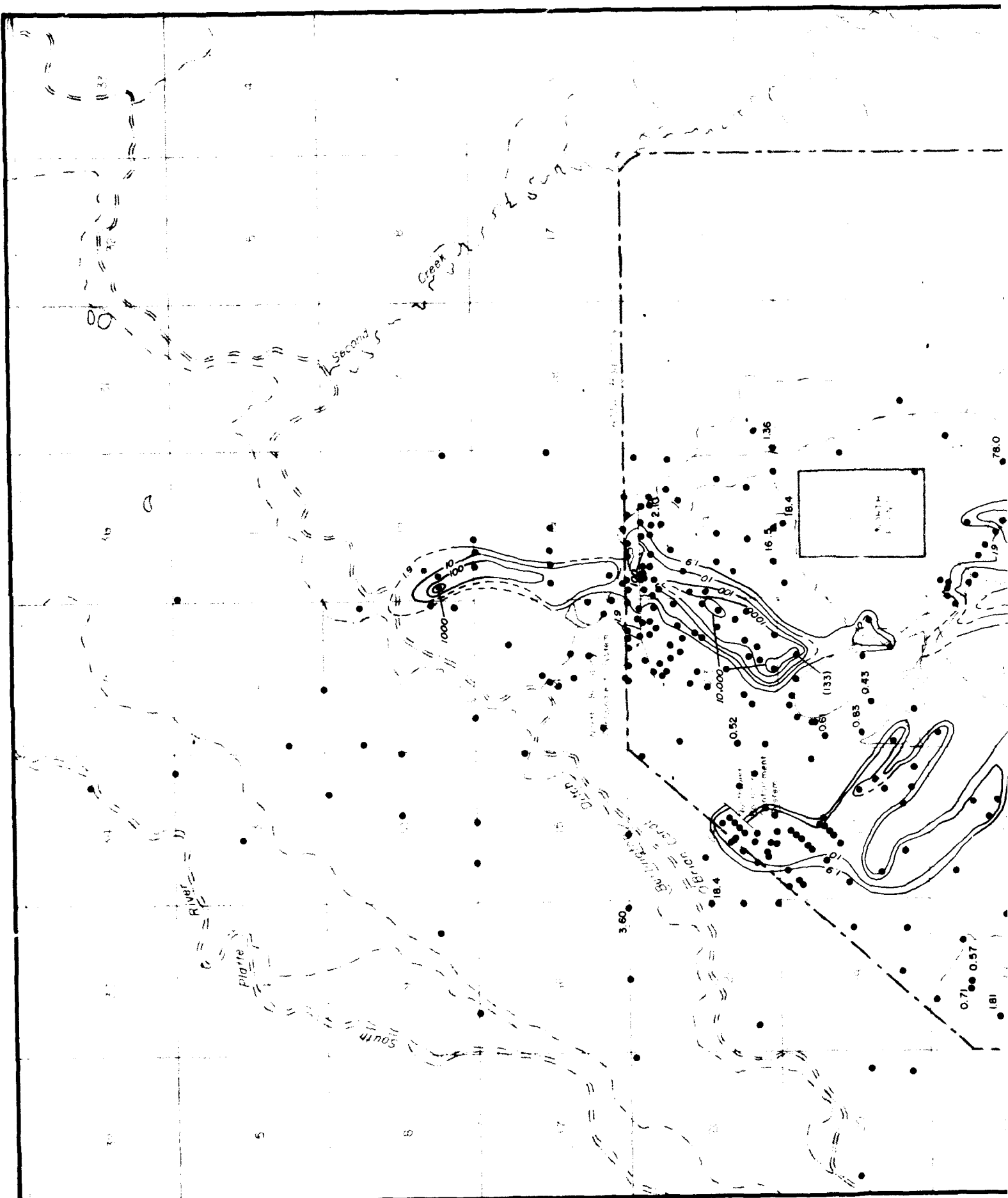
Compounds included in this group are:

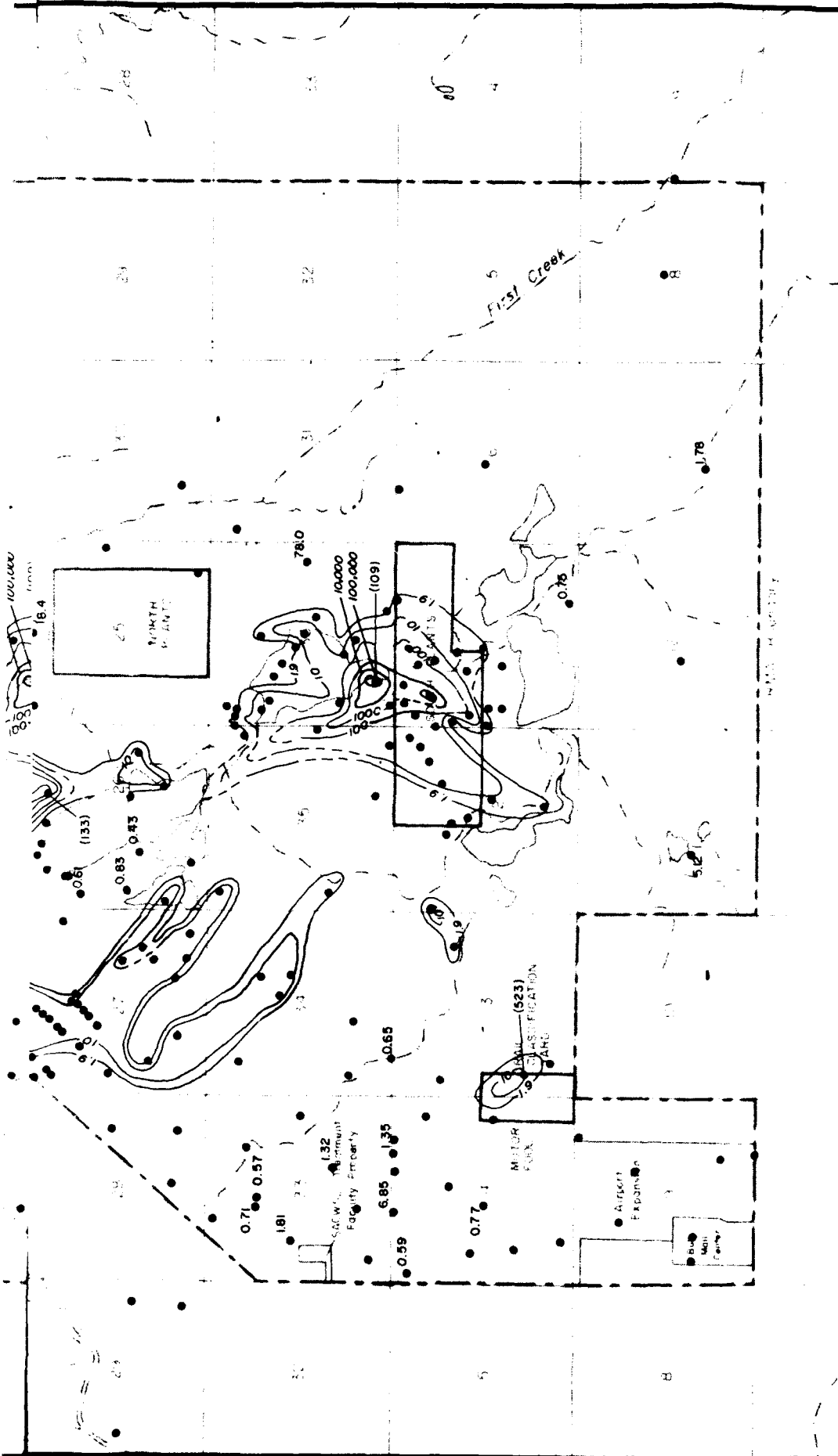
1,1-Dichloroethene	Carbon Tetrachloride	Tetrachloroethene
1,1,1-Trichloroethane	Chloroform	Trichloroethene
1,2-Dichloroethane	Methylene Chloride	
1,1,1-Trichloroethane	Trans-1,2-Dichloroethene	
1,1,2-Trichloroethane		

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FIGURE 4.3-17
Summed Volatile Organohalogen Compound Plumes
Unconfined Ground-Water Flow System
Spring 1988
CMP Ground - Water Monitoring Annual Report
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Harding Lawson Associates





Explanation

— Isoconcentration Line, Dashed where Inferred

● 1.35 Isolated Detection or Concentration less than
(523) Highest CRL, in $\mu\text{g/l}$ (Well Identification N

Isoconcentration Values ($\mu\text{g/l}$)

9.

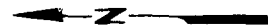
10

100

1000

000,

100,000

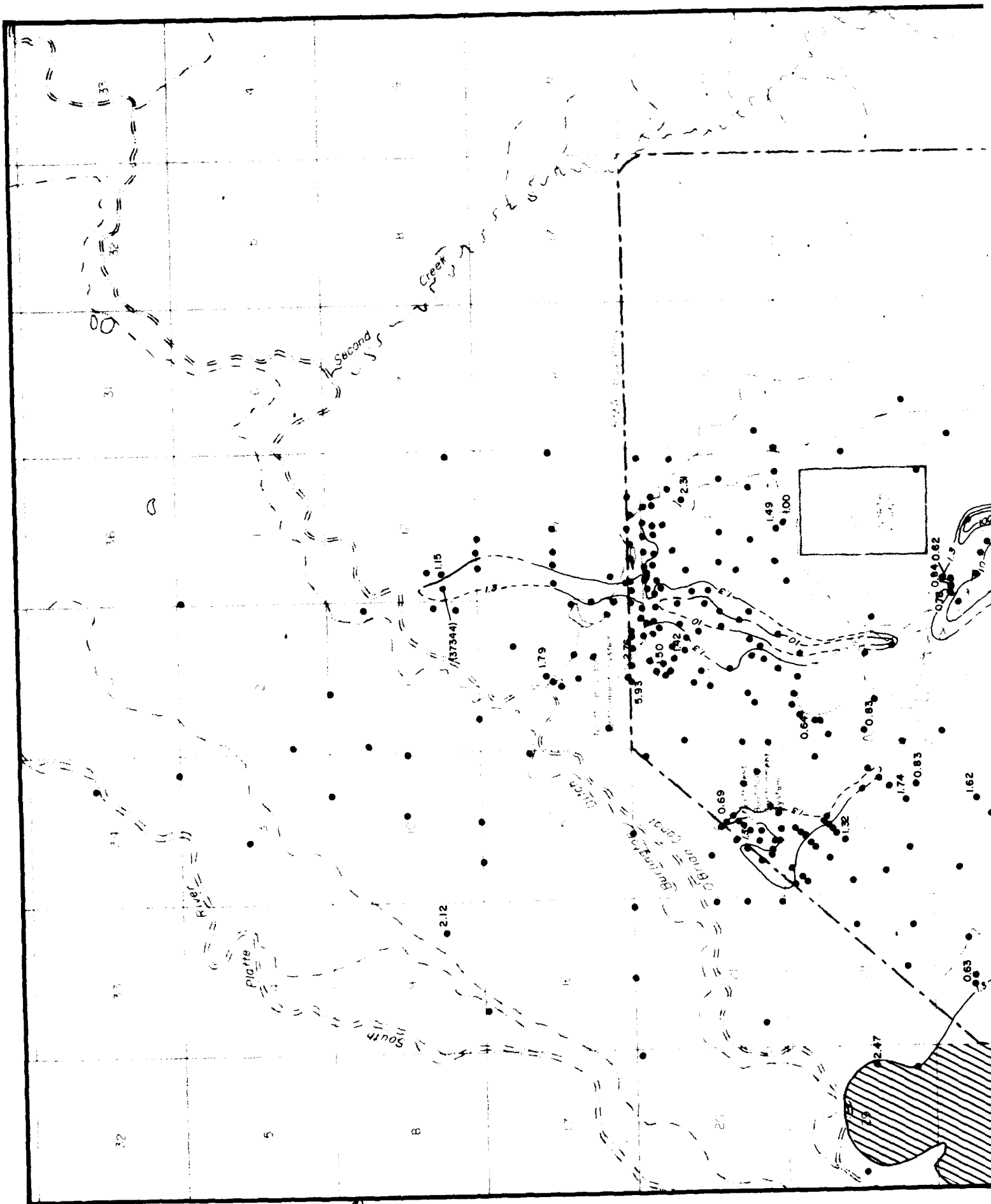


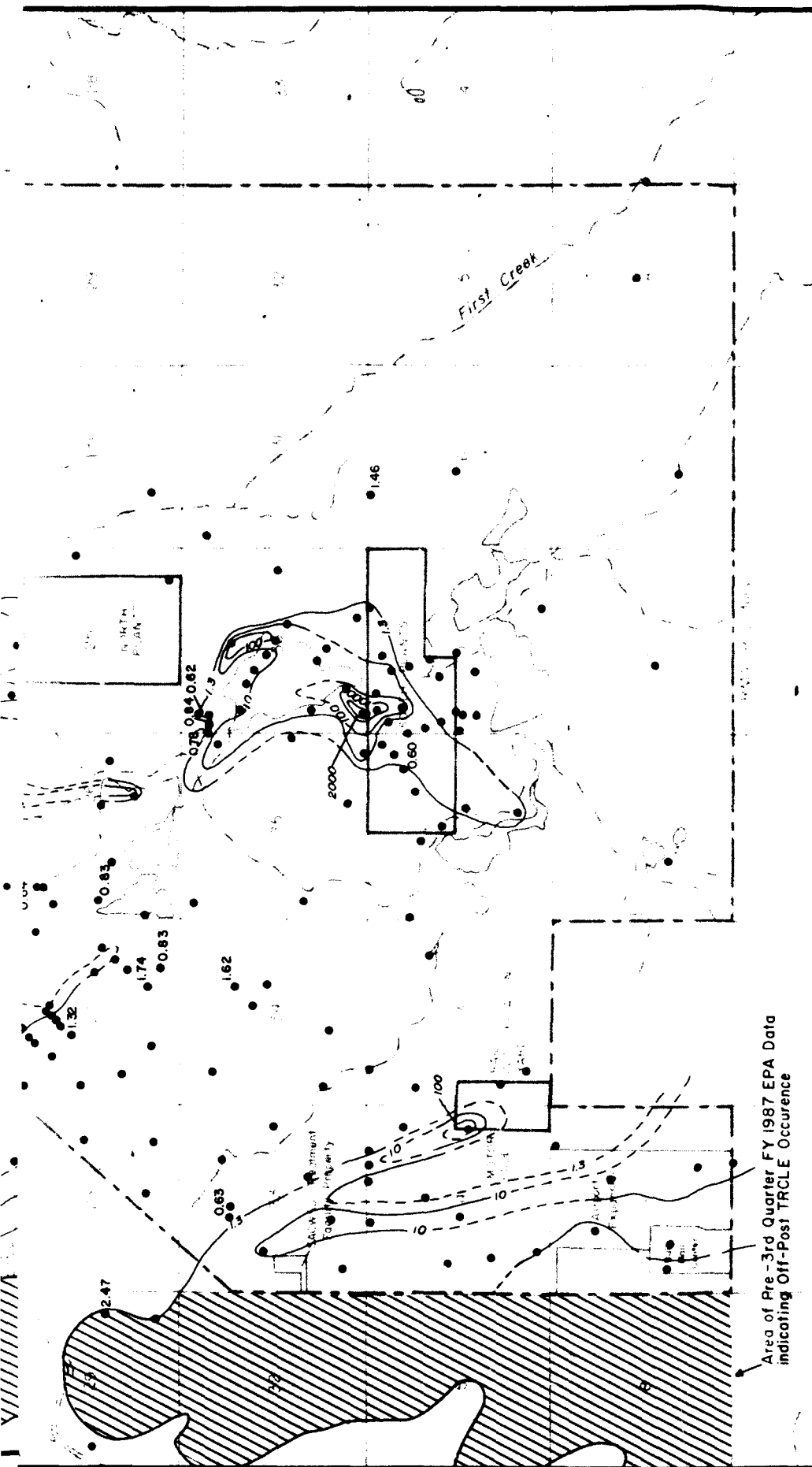
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FIGURE 4.3-18

Chloroform Plumes
Unconfined Ground-Water Flow System
Winter 1987/88
CMP Ground - Water Monitoring Annual Report
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FIGURE 4.3-19
Trichloroethene (TRCLE) Plumes
Unconfined Ground-Water Flow System
Winter 1987/88

CMP Ground - Water Monitoring Annual Report
Prepared by: R.L. Stollar & Associates Inc.
Harding Lawson Associates

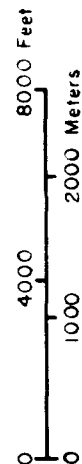
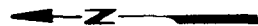
Explanation

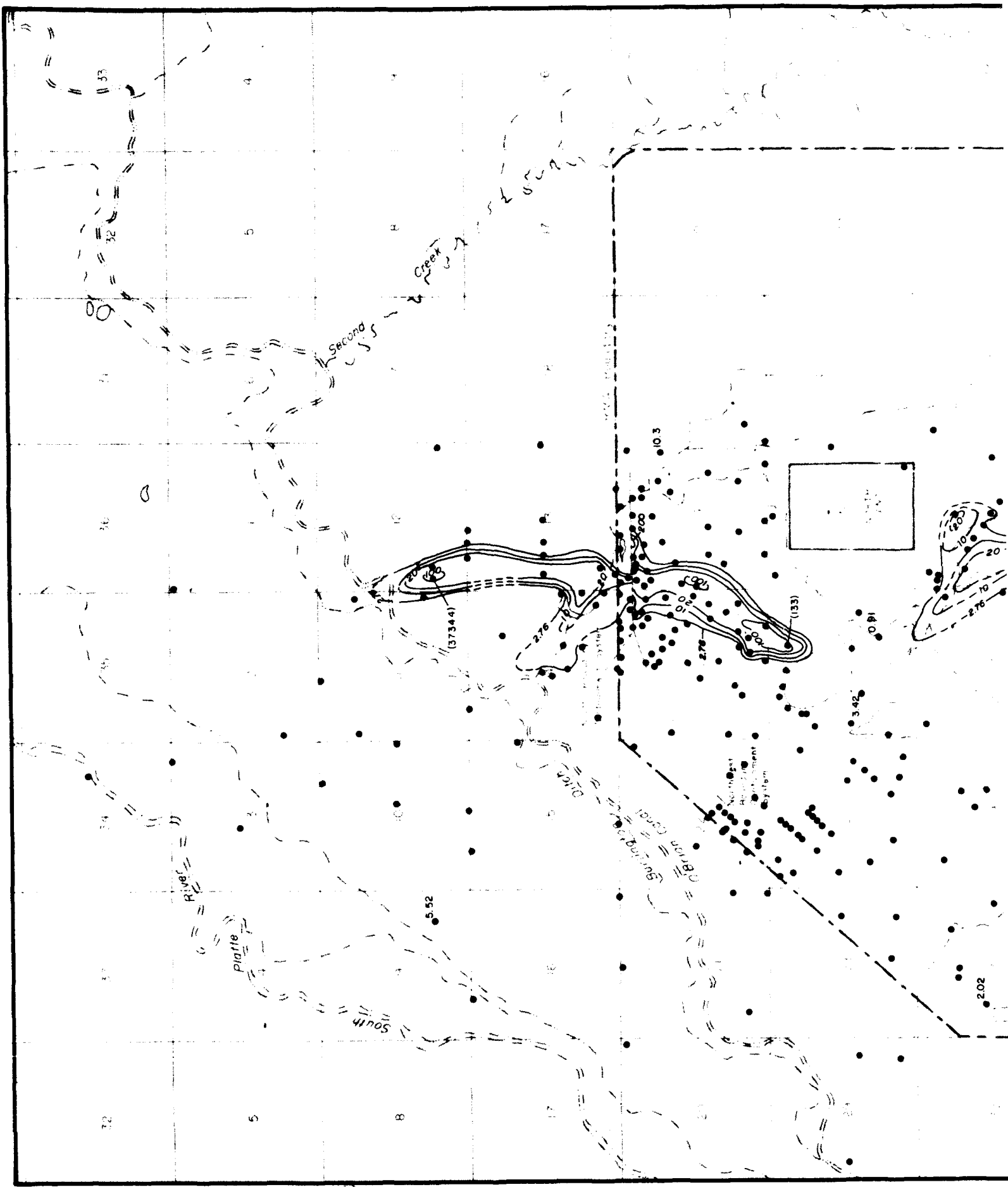
----- Isoconcentration Line, Dashed where Inferred

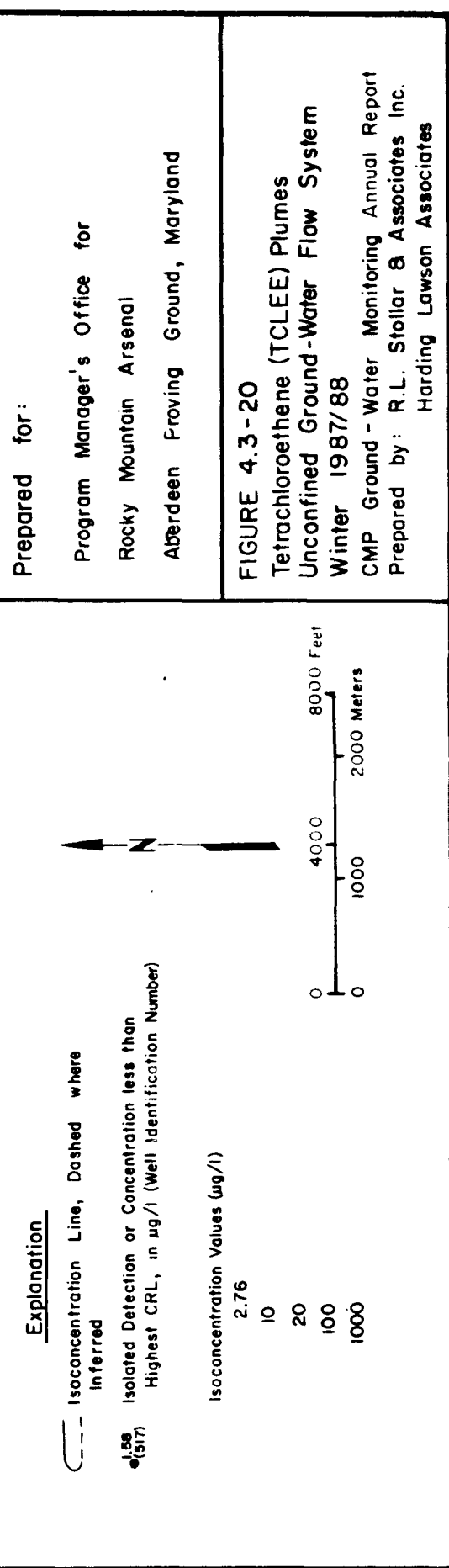
Isolated Detection or Concentration less than
Highest CRL, in $\mu\text{g/l}$ (Well Identification Number)

Isoconcentration Values ($\mu\text{g/l}$)

1.3
10
100
1000
2000

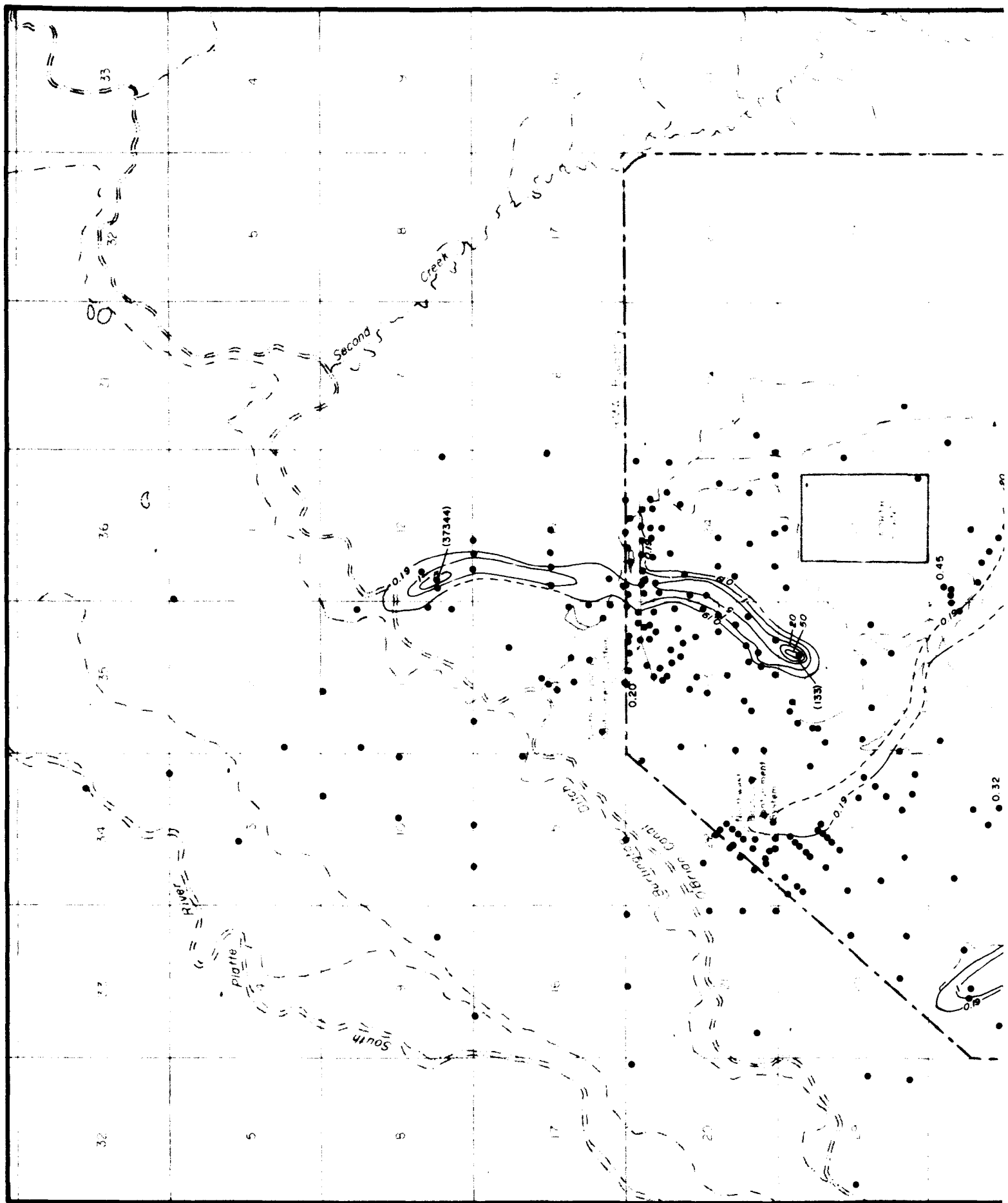


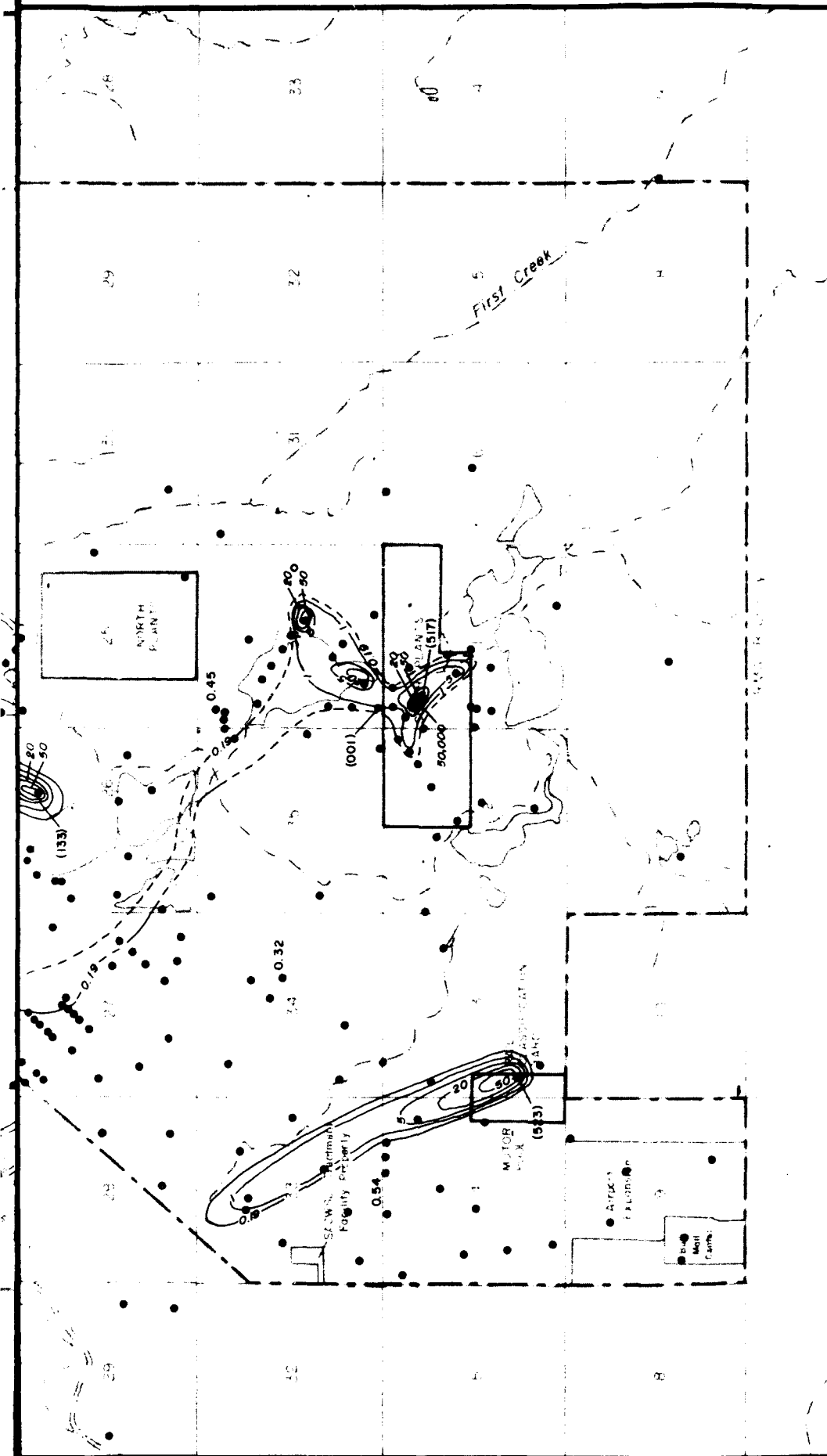




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FIGURE 4.3-20
Tetrachloroethene (TCLE) Plumes
Unconfined Ground-Water Flow System
Winter 1987/88
CMP Ground-Water Monitoring Annual Report
Prepared by: R.L. Stollar & Associates Inc.
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FIGURE 4.3-21

Dibromochloropropane Plumes
Unconfined Ground-Water Flow System
Winter 1987/88

CMP Ground - Water Monitoring Annual Report
Prepared by: R.L. Stollar & Associates Inc.
Harding Lawson Associates

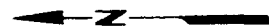
Explanation

— Isoconcentration Line, Dashed where
Inferred

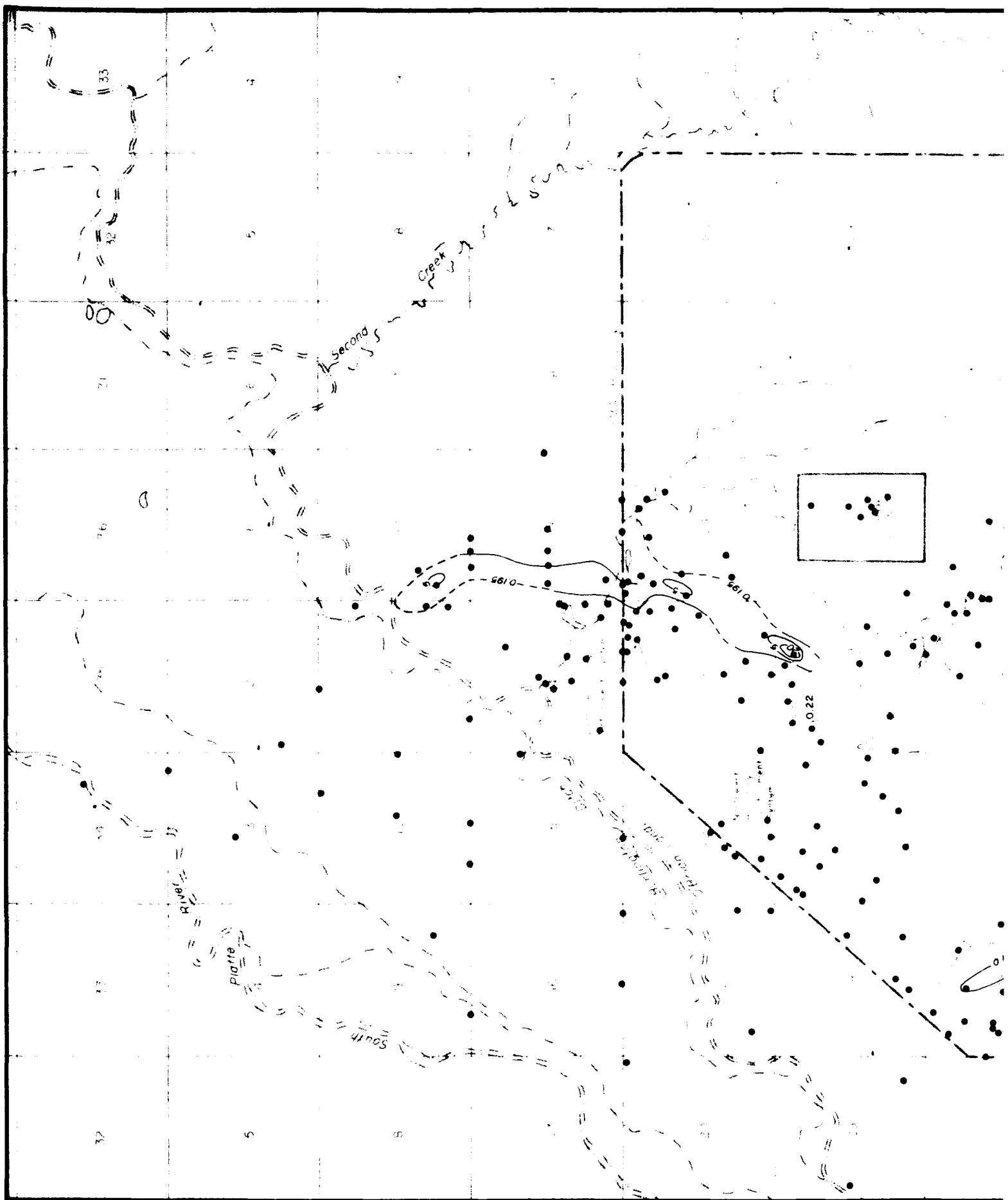
● Isolated Detection or Concentration less than
Highest CRL, in µg/l (Well Identification Number)

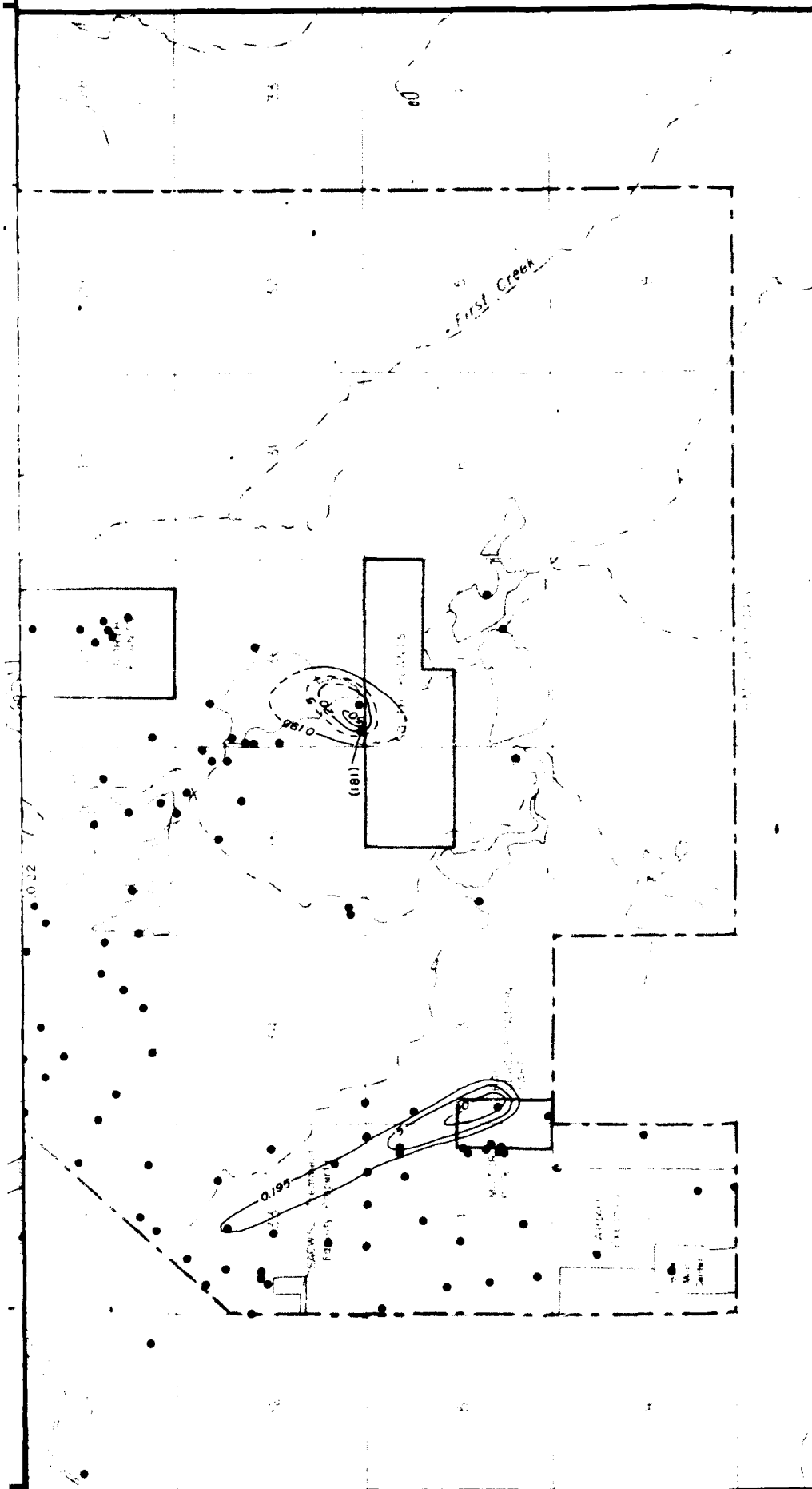
Isoconcentration Values (µg/l)

0.19
1
5
20
50
50,000



0 1000 2000 4000 6000 Feet
0 1000 2000 Meters





Explanation

- Isoconcentration Line, Dashed where Inferred
- Isolated Detection or Concentration less than Highest CRL, in ug/l (Well Identification Number)

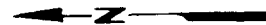
Isoconcentration Values (ug/l)

0.195

5

20

50



0 4000 8000 Feet

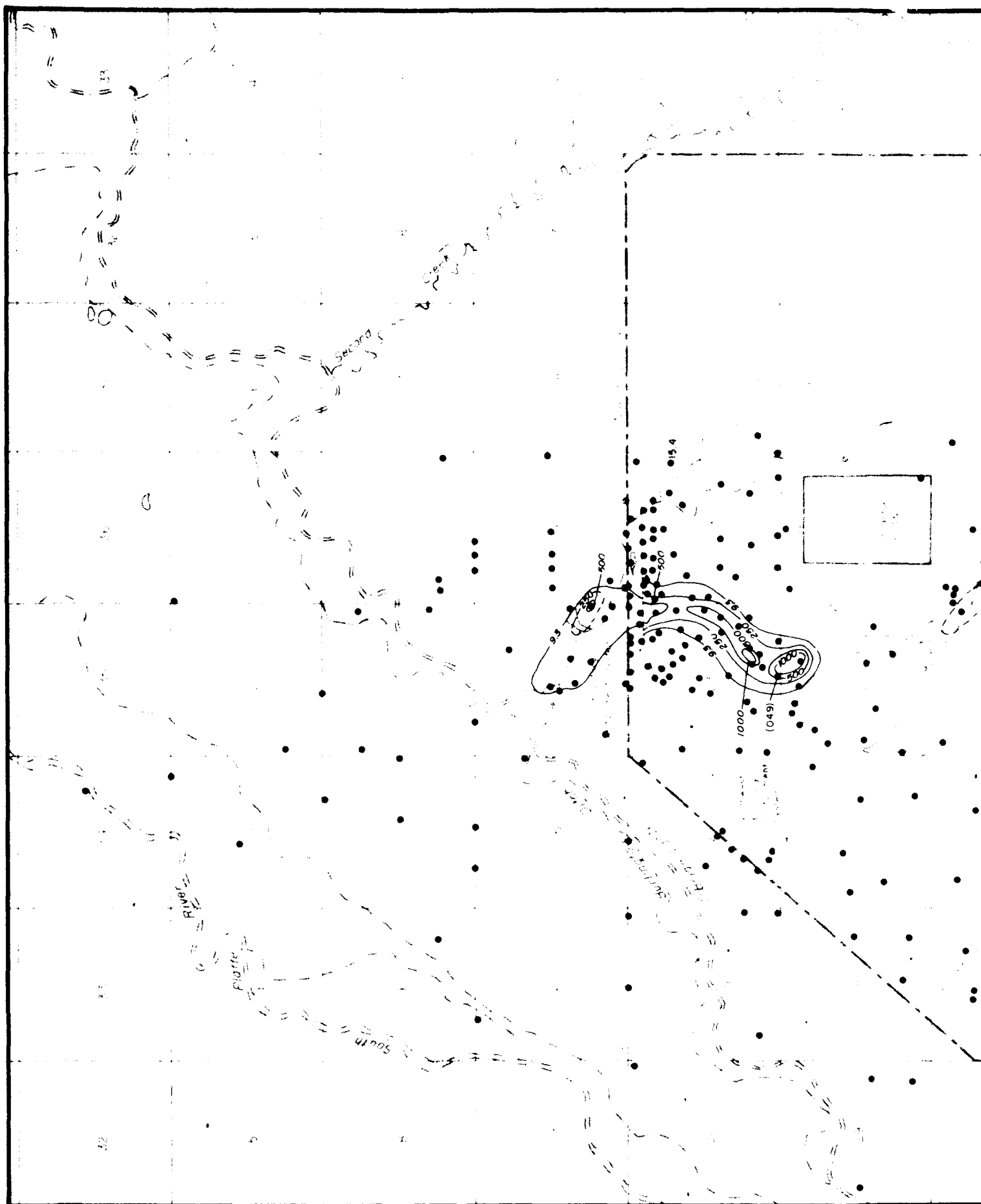
0 1000 2000 Meters

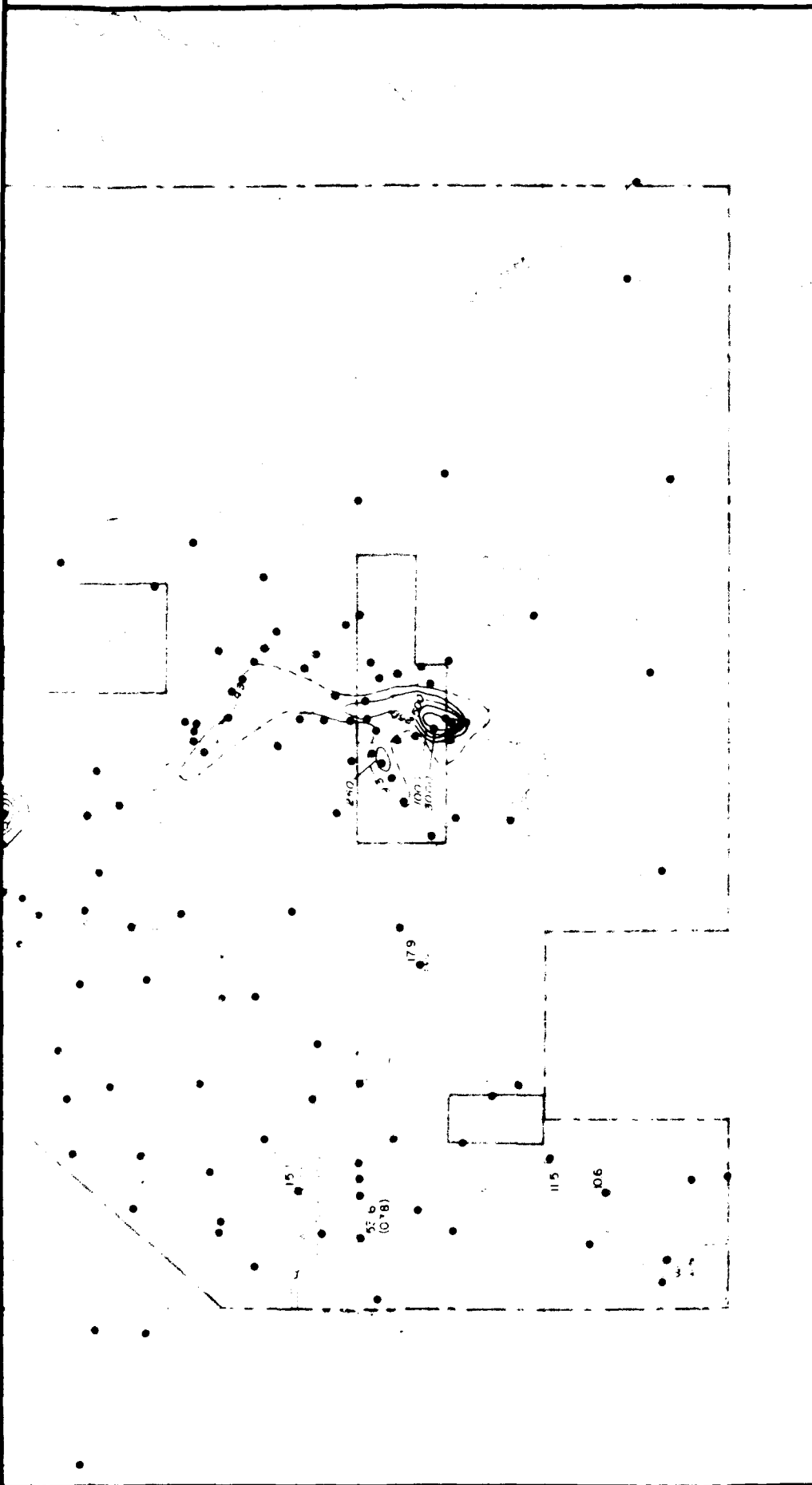
Prepared for:

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Aberdeen Proving Ground, Maryland

FIGURE 4.3-22

Dibromochloropropane Plumes
Unconfined Ground-Water Flow System
Spring 1983
CMP Ground - Water Monitoring Annual Report
Prepared by: R.L. Stollar & Associates Inc.
Harding Lawson Associates





Explanation

- - - Isoconcentration Line, Dashed where Inferred
- 536 (038) Isolated Detection or Concentration less than Highest CRL, in µg/l (Well Identification Number)

Isoconcentration Values: (µg/l)

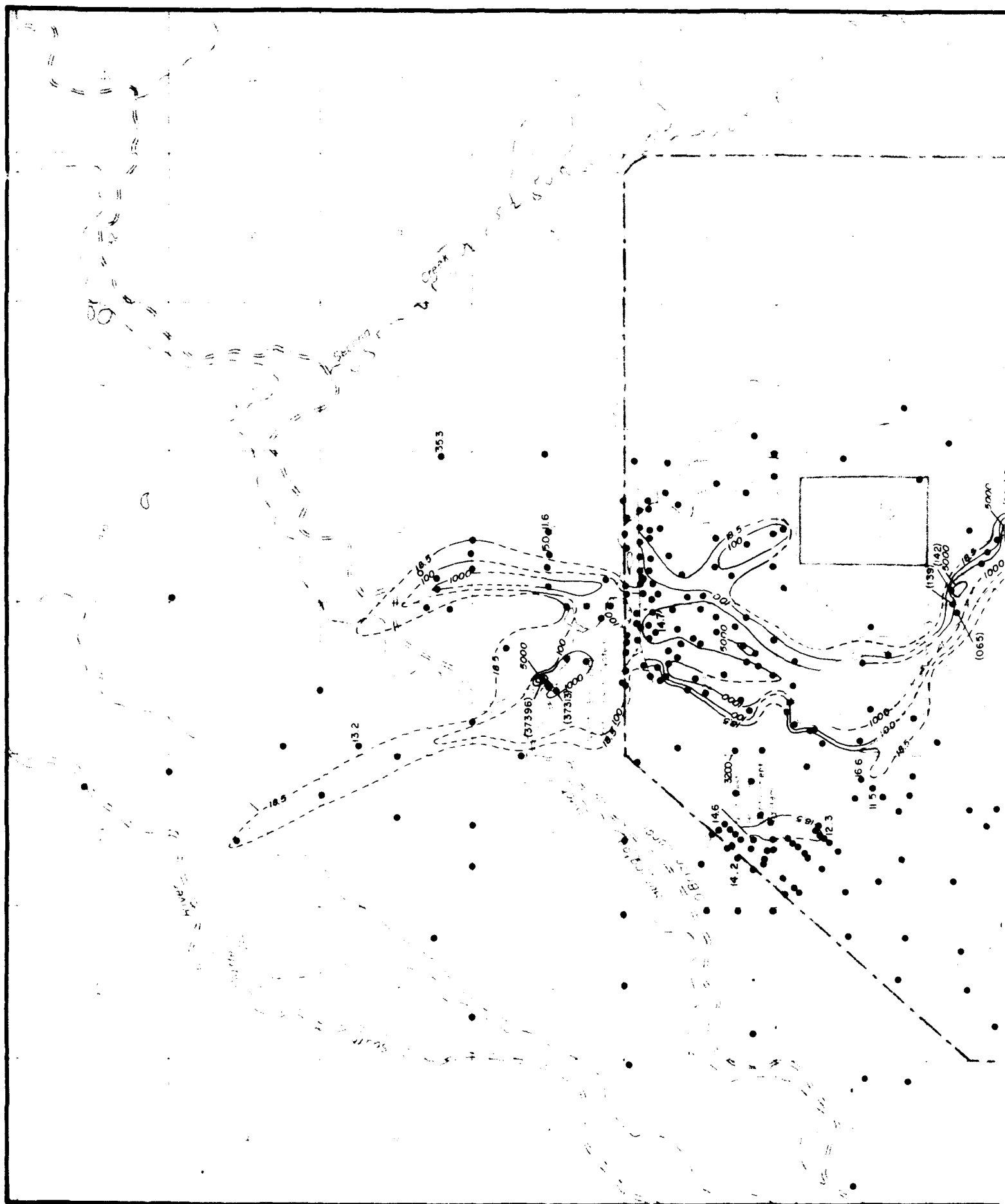
9.3
250
500
1000
3000

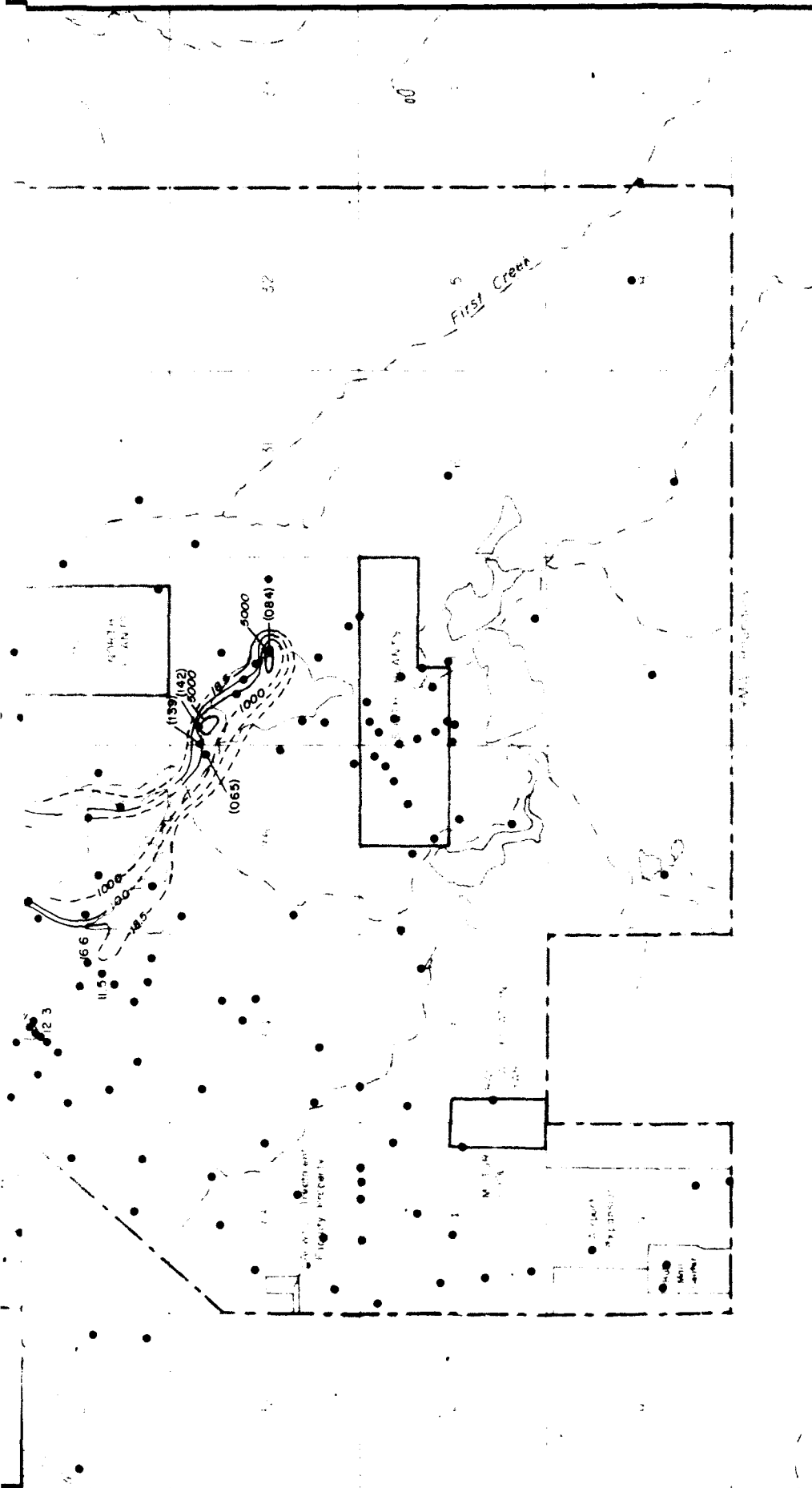
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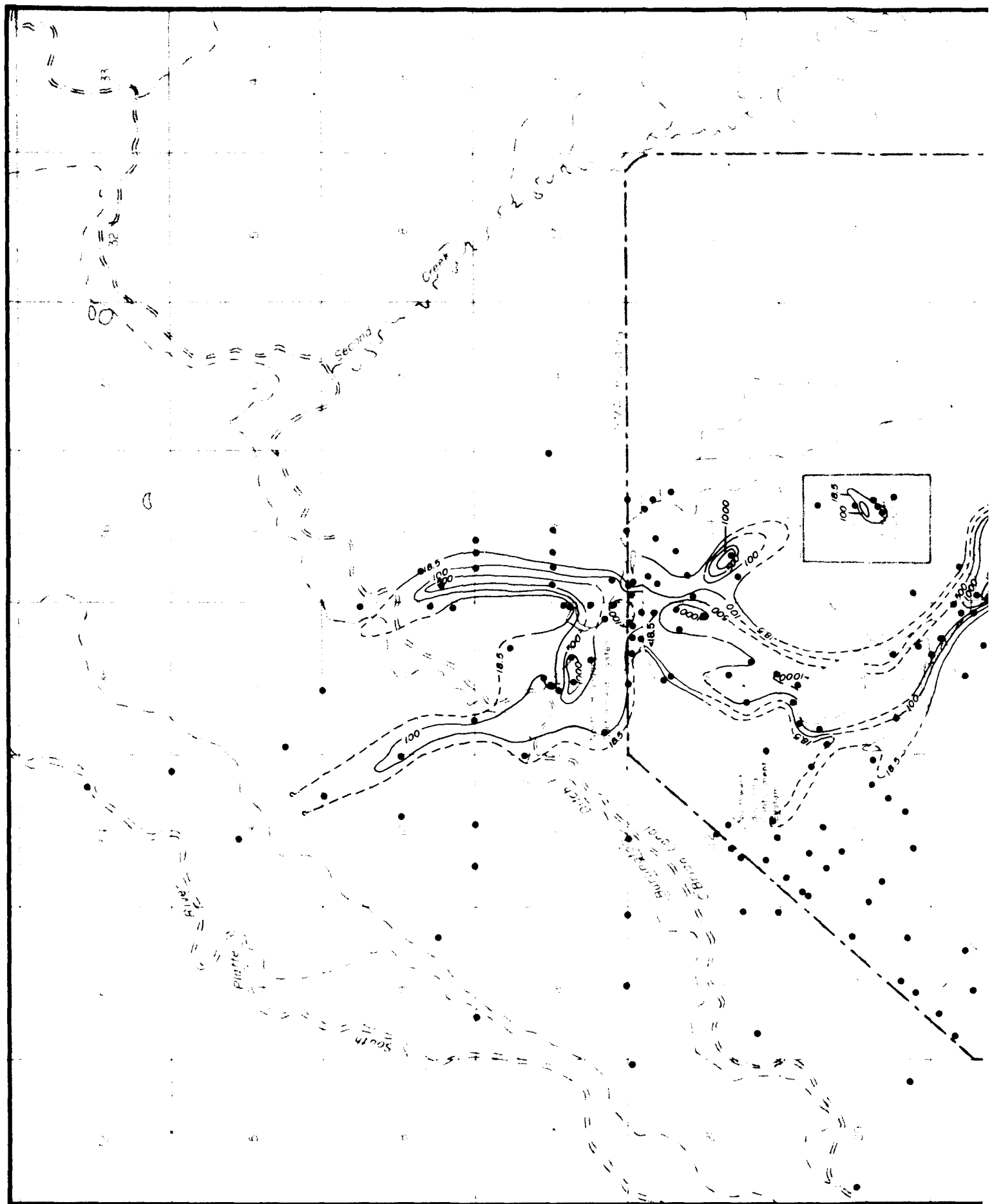
FIGURE 4.3-23

Dicyclopentadiene Plumes
Unconfined Ground-Water Flow System
Winter 1987/88
CMP Ground - Water Monitoring Annual Report
Prepared by: R.L. Stollar & Associates Inc.
Harding Lawson Associates





<p>Prepared for:</p> <p>Program Manager's Office for Rocky Mountain Arsenal Aberdeen Proving Ground, Maryland</p>	<p>FIGURE 4.3-24 Diisopropylmethylphosphonate Plumes Unconfined Ground-Water Flow System Winter 1987/88 CMP Ground - Water Monitoring Annual Report Prepared by: R.L. Stollar & Associates Inc. Harding Lawson Associates</p>
<p><u>Explanation</u></p> <p>--- Isoconcentration Line, Dashed where Inferred</p> <p>• (142) Isolated Detection or Concentration less than Highest CRL, in µg/l (Well Identification Number)</p> <p>Isoconcentration Values (µg/l)</p> <p>18.5 100 1000 5000</p>	<p>0 1000 4000 8000 Feet 0 2000 Meters</p> <p>N</p>





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Program Manager's Office for
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 Aberdeen Proving Ground, Maryland

FIGURE 4.3-25

Diisopropylmethylphosphonate Plumes
 Unconfined Ground-Water Flow System
 Spring 1988

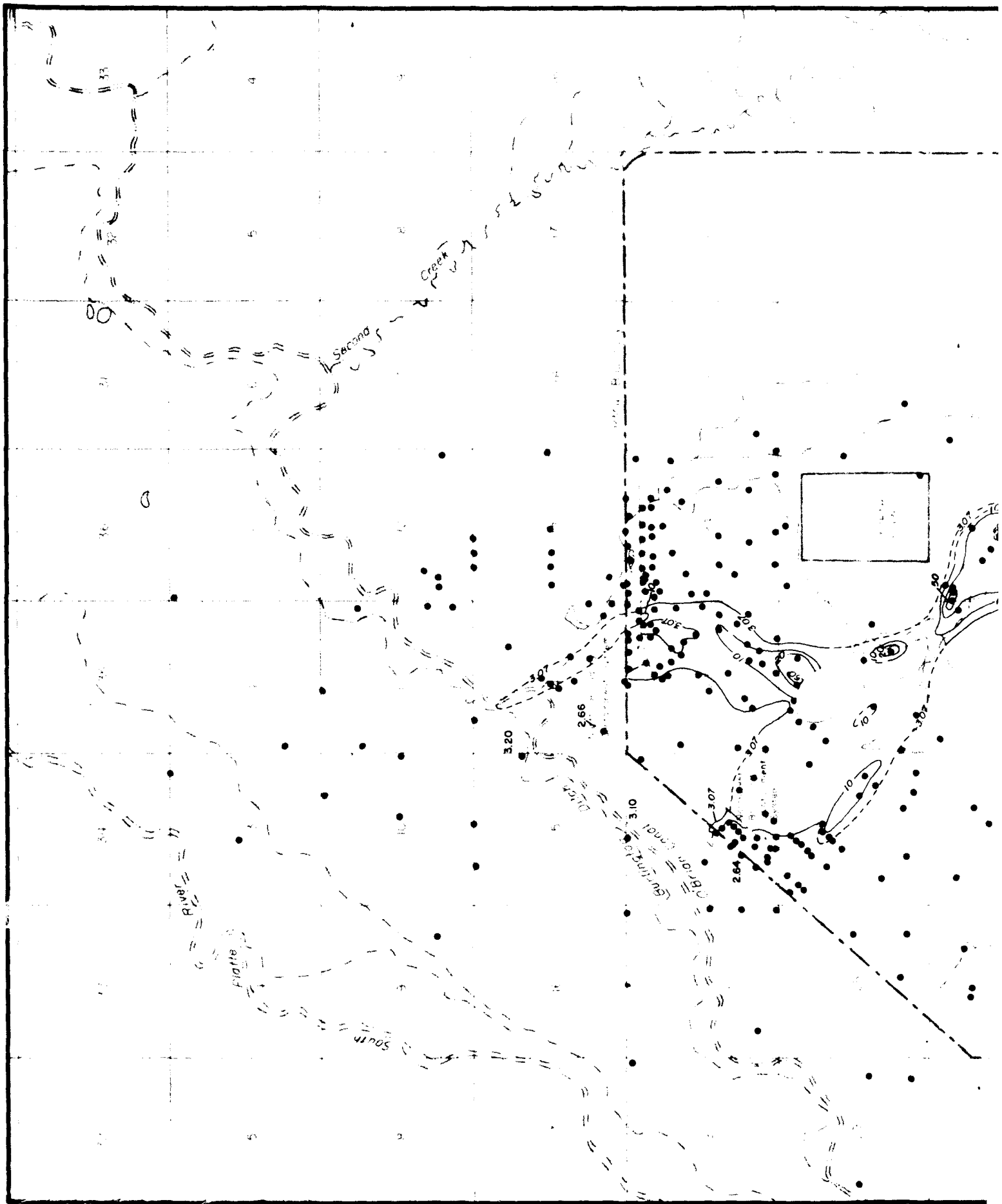
CMP Ground-Water Monitoring Annual Report
 Prepared by: R.L. Stollar & Associates Inc.
 Harding Lawson Associates

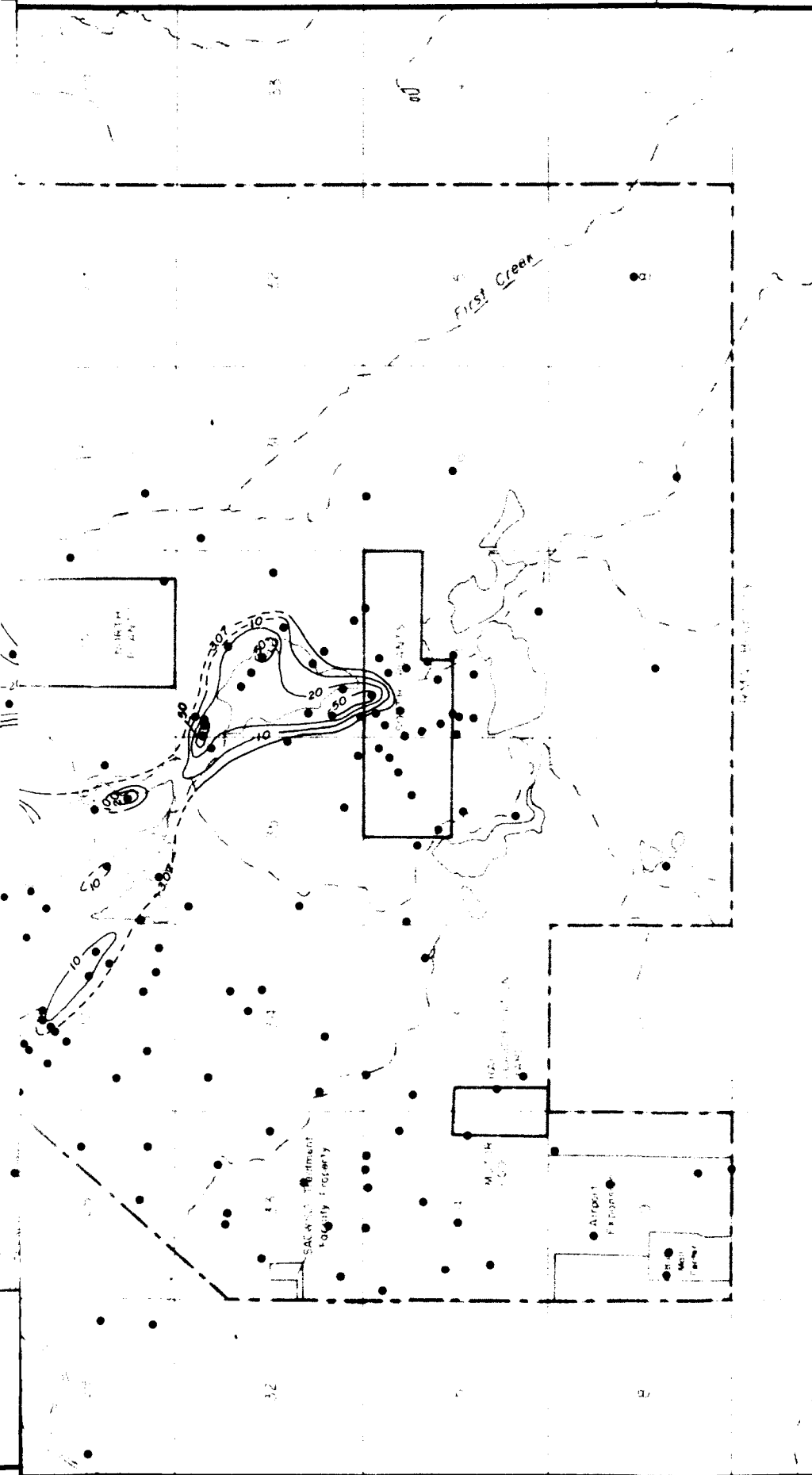
Explanation

- Isocentration Line, Dashed where Inferred
- Isolated Detection or Concentration Less than Highest CRL, in $\mu\text{g/l}$
- - - Extent of Plume not Fully Evaluated During Semi-Annual Specific Area Monitoring

Isocentration Values ($\mu\text{g/l}$)

- 18.5
- 100
- 500
- 1000
- 10000



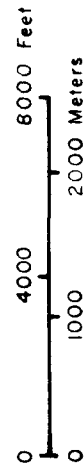
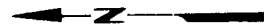


Explanation

- Isoconcentration Line, Dashed where Inferred
- 3.20 Isolated Detection or Concentration Less than Highest CRL, in $\mu\text{g/l}$

Isoconcentration Values ($\mu\text{g/l}$)

3.07
10
20
50

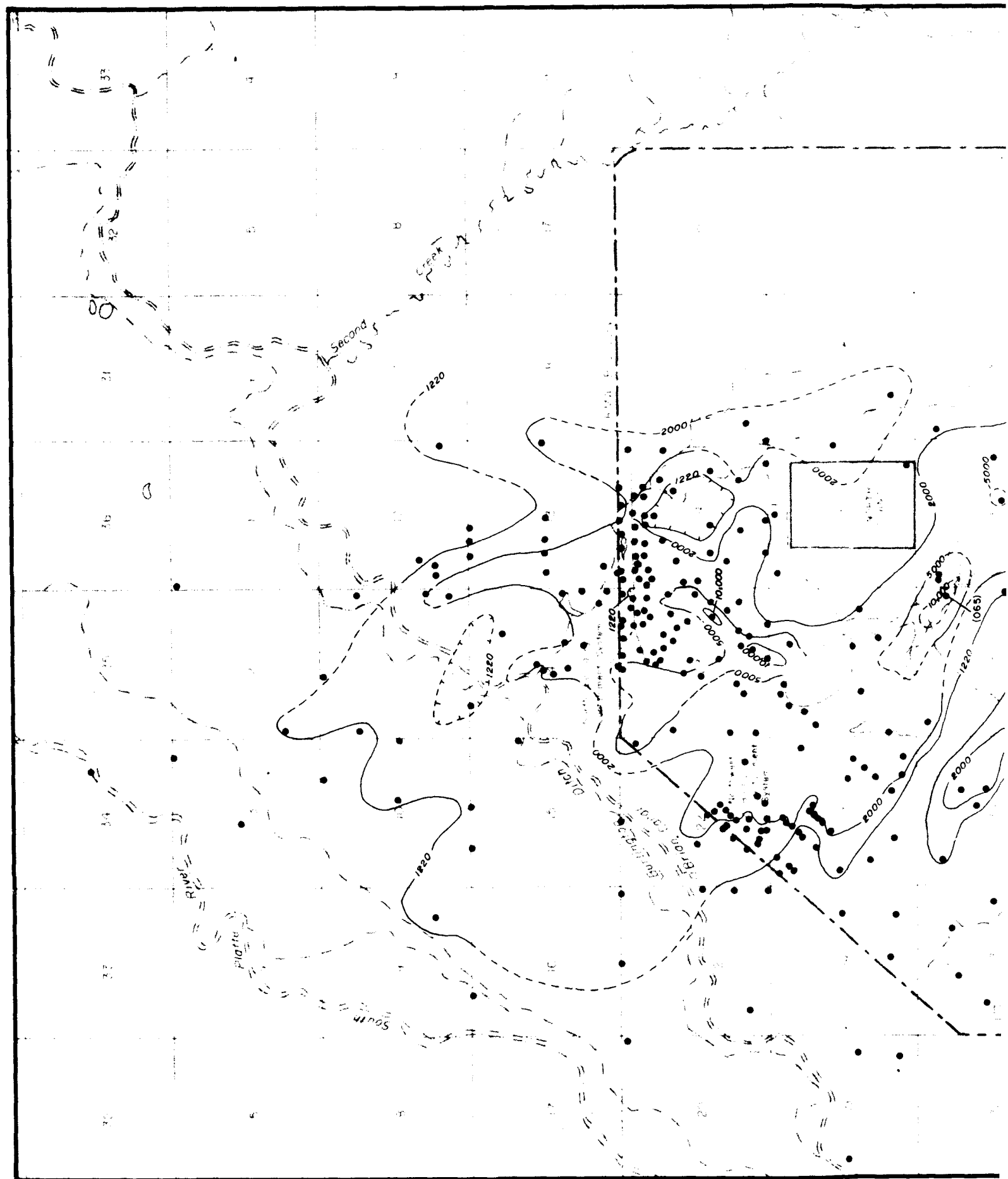


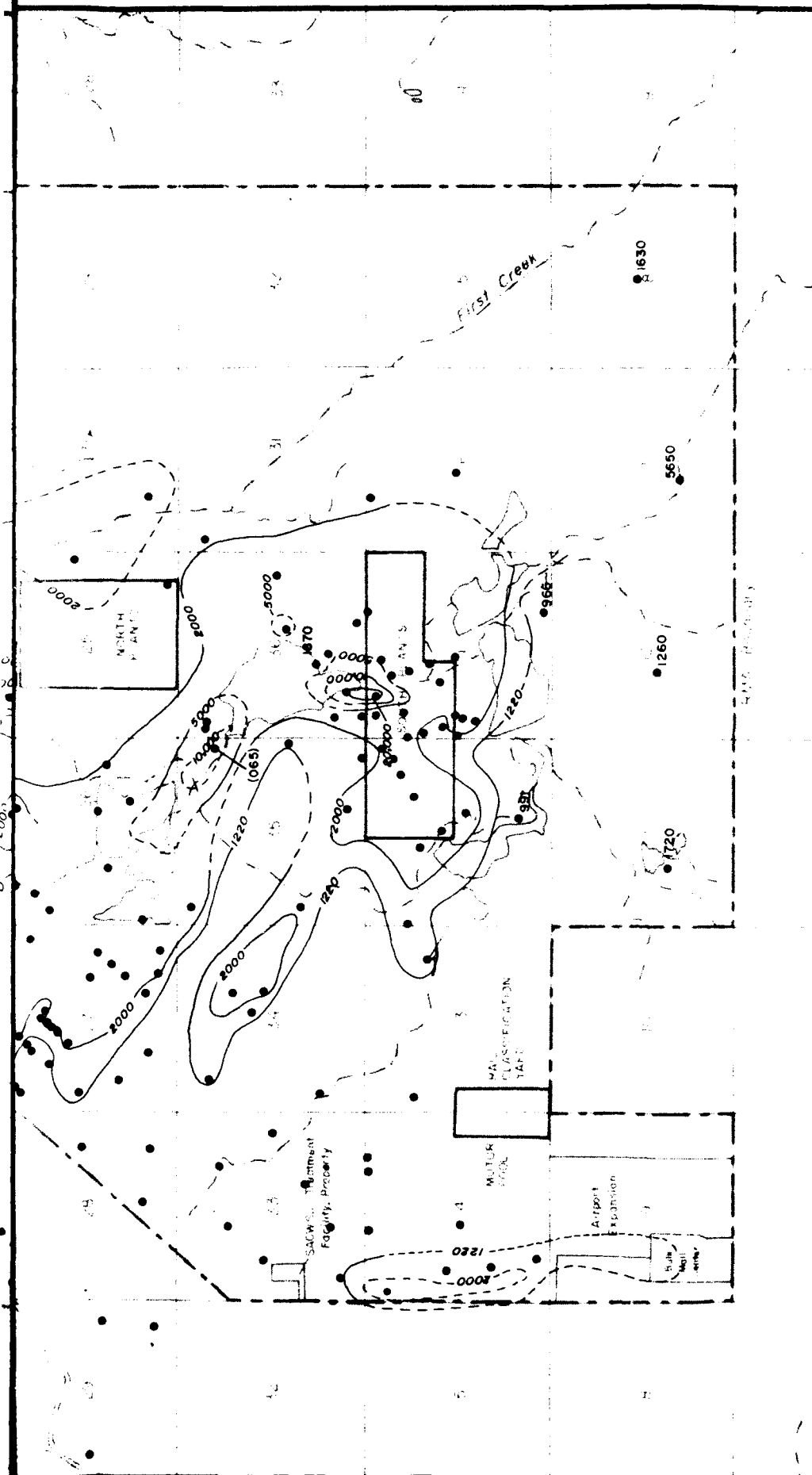
Prepared for:

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Aberdeen Proving Ground, Maryland

FIGURE 4.3-26
Arsenic Plumes
Unconfined Ground-Water Flow System
Winter 1987/88

CMP Ground - Water Monitoring Annual Report
Prepared by: R.L. Stollar & Associates Inc.
Harding Lawson Associates





Prepared for:

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Aberdeen Proving Ground, Maryland

FIGURE 4.3-27

Fluoride Distribution
Unconfined Ground-Water Flow System
Winter 1987/88

CMP Ground - Water Monitoring Annual Report
Prepared by: R.L. Stollar & Associates Inc.
Harding Lawson Associates

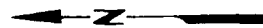
Explanation

— Isoconcentration Line, Dashed where
Inferred

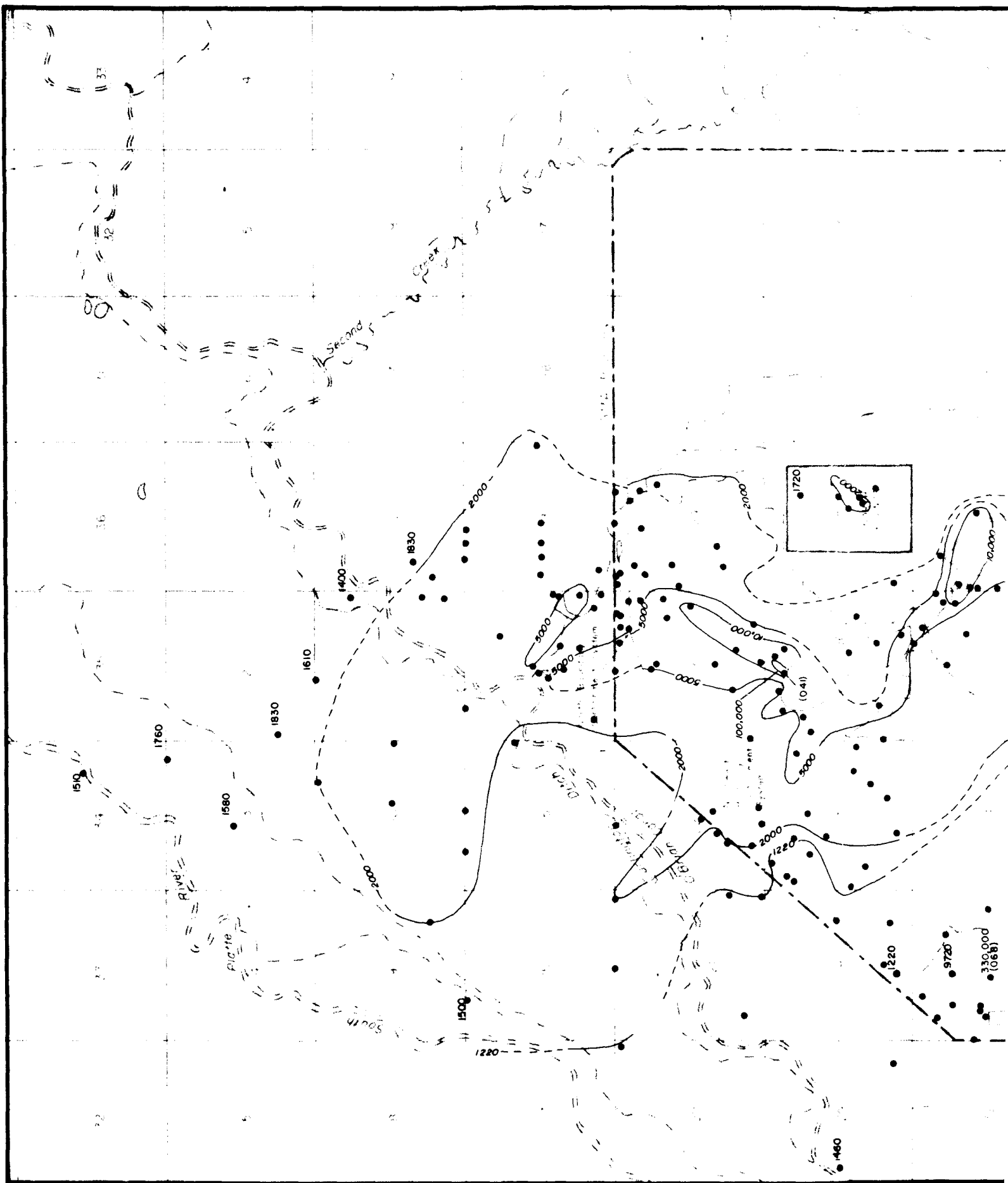
● Isolated Detection or Concentration less than
Highest CRL, in ug/l (Well Identification Number)

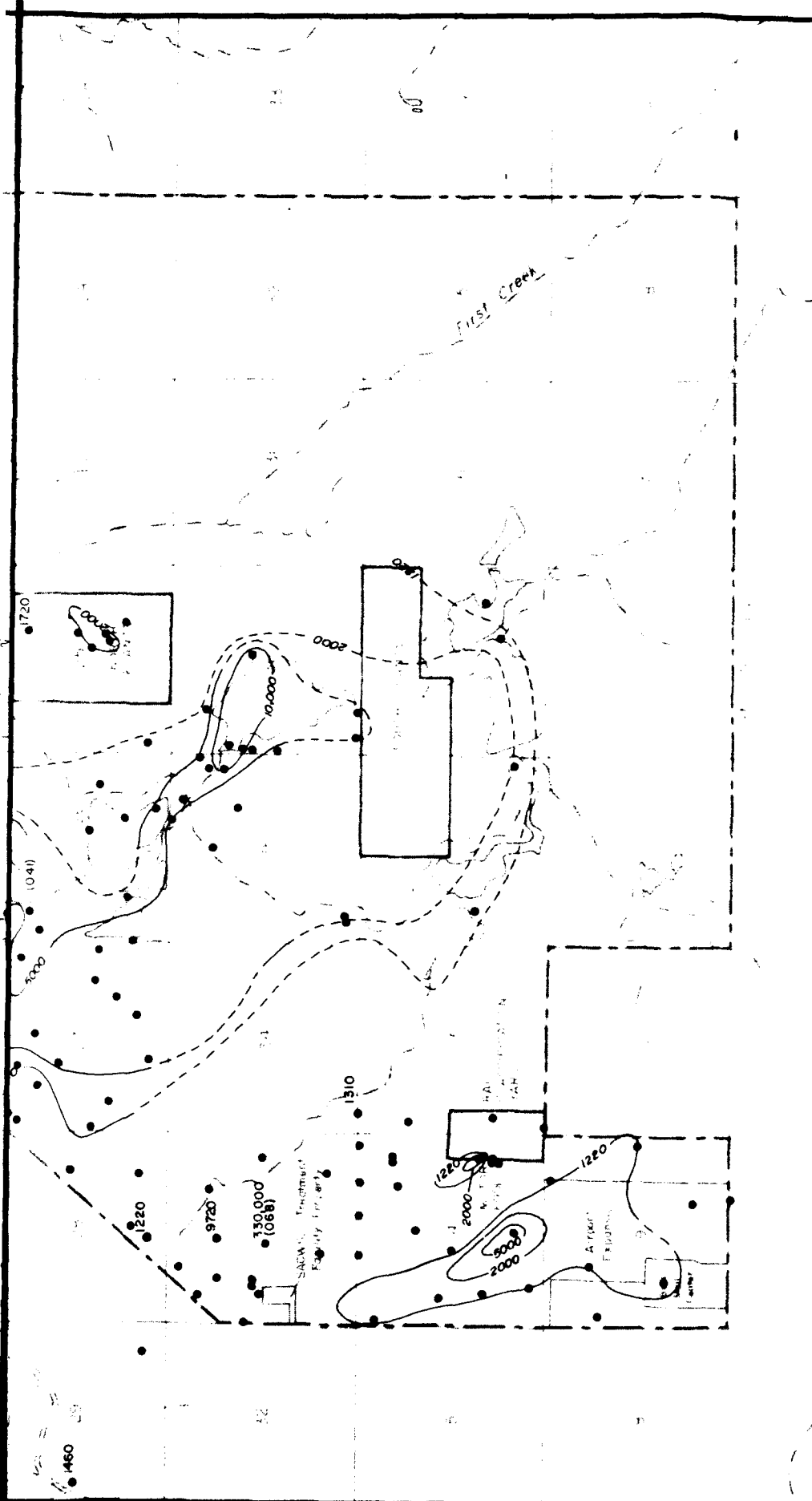
Isoconcentration Values (ug/l)

1220
2000
5000
10,000
20,000

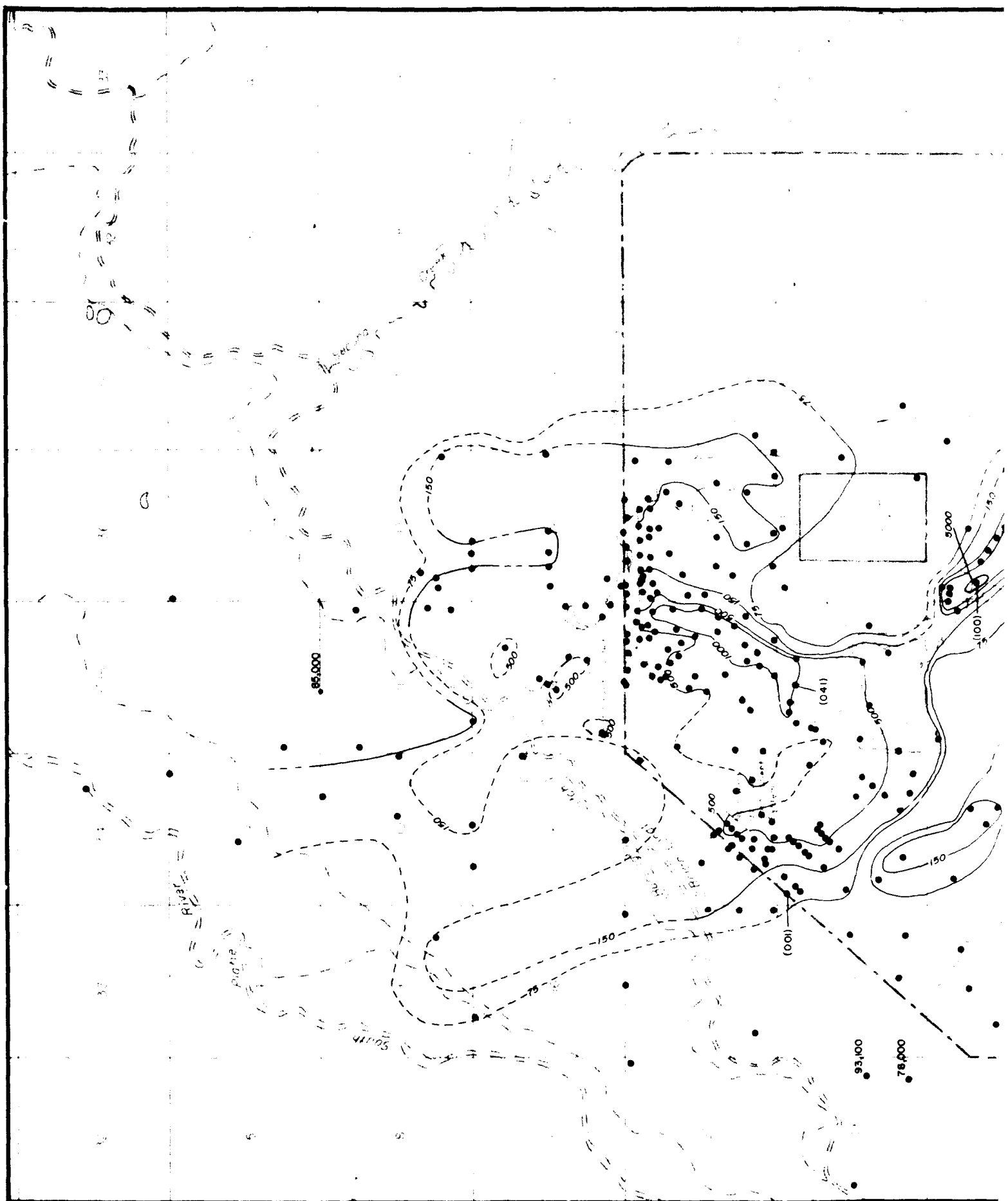


0 1000 2000 4000 8000 Feet
0 1000 2000 Meters





<p>Prepared for:</p> <p>Program Manager's Office for Rocky Mountain Arsenal Aberdeen Proving Ground, Maryland</p>	<p>FIGURE 4.3-28 Fluoride Distribution Unconfined Ground-Water Flow System Spring 1988 CMP Ground - Water Monitoring Annual Report Prepared by: R.L. Stollar & Associates Inc. Harding Lawson Associates</p>
<p><u>Explanation</u></p> <p>----- Isoconcentration Line, Dashed where Inferred</p> <p>• 1220 (063) Isolated Detection or Concentration less than Highest CRL, in µg/l (Well Identification Number)</p> <p>Isoconcentration Values (µg/l)</p> <p>1220 2000 5000 10,000 100,000</p>	<p>North Arrow</p> <p>Scale: 0 to 8000 Feet / 0 to 2000 Meters</p>



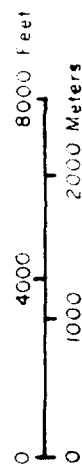


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5.0 DATA ASSESSMENT

Ground-water data collected during FY88 as part of the CMP consisted of quarterly water-level data and water-quality data collected at intervals ranging from quarterly to annually. Data assessments will be presented from three perspectives. First, anthropogenic influences on data assessments will be discussed to assess the representativeness of CMP data. Second, potentiometric data will be discussed as they relate to contaminant migration. Third, water quality data will be assessed on the basis of contaminant distributions described in Section 4.0 and hydrogeologic conditions at the site. Water-quality interpretation will include discussion of source areas, remedial systems, continuity of plumes, degradation of chemicals, relationships between contaminant distributions and geologic units, and the maximum areal and vertical extent of contaminated ground water.

For simplicity, contamination at RMA often is characterized with composite maps representing the distribution of a group of similar chemicals. The mapped extent of the group of chemicals represents the contaminant(s) that exist in greatest concentrations and/or those that are the most mobile in the environment. In some cases when using composite plume maps to describe contamination at RMA, relatively simple assessments are appropriate. Composite plume maps are not appropriate when considering relationships among specific contaminants, differences in source areas, and the efficacy of remedial systems.

Degradation of organic contaminants in the environment can influence some contaminant distributions. For example, the distribution of the organochlorine pesticides Aldrin and Dieldrin is better understood by considering their relationships to each other. Dieldrin, though produced at RMA directly, is also a breakdown product of Aldrin, and is more persistent in the environment than is Aldrin. The presence of DCPD in relationship to the distributions of Aldrin and Dieldrin may be explained in part by its use in the manufacture of both Aldrin and Dieldrin. Further discussion of the impacts of breakdown products in assessing contamination is provided in Section 5.3.3.

There is potential for vertical as well as areal contaminant migration at RMA. Because the highest levels of RMA contamination exist in the unconfined flow system, this system has been the most intensely studied and remediated. However, vertical contaminant migration into the confined flow system could impact contaminant plume geometries in the unconfined system, contaminant concentrations of deeper aquifers in the area, and contaminant migration to the off-post area.

Contaminant migration pathways have been identified for the unconfined flow system in Section 2.0. However, the mechanisms of vertical migration are less well understood, as are mechanisms of areal transport in the confined flow system. Contaminant distributions that provide insight regarding the flowpaths are highlighted where available.

5.1 Anthropogenic Influences on Data Assessments

Anthropogenic influences are those man-induced variables that affect the perspective from which the data are assessed. These influences include the well network(s) sampled, regulatory requirements, CRLs used to present and compare results, and variations in laboratory analytical method. Due to their potential impacts on data assessment, a discussion of these influences is provided.

5.1.1 Monitoring Network Design

Ground-water data were obtained during FY88 using three different sampling networks: annual, semiannual and quarterly. The number of wells included 467 for the annual network, 307 for the semiannual network, and 46 for the quarterly network. The annual and semiannual networks were designed to provide monitoring data throughout RMA, while quarterly data pertained only to the Basin F area. The network selected for semiannual monitoring is focused in 9 specific areas. Water-quality data generally were not available between these specific areas. The intervening information available from the larger, annual network is necessary to demonstrate plume continuity between the specific areas. Impacts of variable networks on data assessment are illustrated in this report by using only the annual and semiannual events. Two cases are presented.

A comparison of the winter 1987/88 and spring 1988 Dieldrin plume maps (Figures 4.3-6 and 4.3-7, respectively) illustrates that the larger winter 1987/88 network allows for a more thorough assessment of the plume configurations. The absence of data from spring 1988 monitoring in the South Plants makes it impossible to contour the southern portion of the plume originating in the South Plants. The absence of water-quality monitoring data from wells in the South Plants for spring 1988 similarly limits the assessment of the southward extension of other plumes, such as benzothiazole and summed volatile aromatic compounds (VOAs), that originate in the South Plants.

Another case involves the summed VOA plumes in Figures 4.3-12 and 4.3-13. The difference in plume configurations is readily apparent, especially where analytical results were either obtained from a smaller network, as in off-post areas, or were unavailable, as in the South Plants.

Figures A-24 through A-31, and A-32 through A-36 present confined flow system zone VOA detections for the winter 1987/88 and spring 1988 events, respectively. The impact of using different networks for the two periods is also evident in the Denver Formation. For example, in zone 1, spring 1988 data show VOAs occur as far south as southern Section 35 (Figure A-34), while winter 1987/88 data show VOA extent in the south limited to northern Section 35 in zone 1 (Figure A-27). This change in apparent extent of contamination is a function of using different networks to assess contamination extent.

5.1.2 Applicable or Relevant and Appropriate Requirements

Applicable or Relevant and Appropriate Requirements (ARARs) have not been finalized for contaminants in ground water at RMA. As a result, definitive guidelines do not exist to assess the extent of contamination and/or the need for remediation. Therefore, the extent of contamination for organic compounds that do occur naturally is assessed relative to the CRL. For inorganic analytes, data are assessed with respect to background levels in the environment. Although investigators have disagreed on the definition of background levels, values used to assess inorganic contamination in this report are considered above federal primary and secondary drinking water standards.

It is possible that ARARs will be established at values greater than the CRLs or background levels used in this report. If this happens, the data assessment given in this report provides greater detail than is needed to protect public health and the environment, particularly with regard to widespread contaminants of comparatively low toxicity, such as DIMP. It is not possible to fully assess the impacts of contaminant levels at various concentrations without guidance levels against which to gauge the relative severity of that contamination. Several analytes serve to illustrate this point.

In the vicinity of the Northwest Boundary Containment System, Dieldrin, VOAs and VOHs (Figures 4.3-6, 4.3-12 and 4.3-16), occur to the south of the system and extend into the off-post area. Without guidance levels or ARARs to assess the danger these contaminant levels pose to off-post populations, it is not possible to evaluate whether contaminants downgradient of the Northwest Boundary Containment System should be remediated.

Further illustration of the potential impact of ARARs on data assessments is provided by contamination north of the North Boundary Containment System. In the northern off-post area, DIMP extends over 15,000 ft off-post (Figure 4.3-24). However, concentrations for 8,000 ft at the northern end of the plume are between 18.5 and 100 $\mu\text{g/l}$. Federal regulatory guidance on this

chemical may recommend standards above the 100 µg/l level. If ARARs were at similarly high concentrations, the extent of the plume area of concern would effectively be reduced by over 50 percent.

5.1.3 Laboratory Analysis and Reporting

Procedures for analyzing water samples affect how the extent of RMA contamination is perceived. There are differences in analytical methods used by the three project laboratories, differences in Certified Reporting Limits (CRLs) among these labs, variations due to sample dilution, and differences in the precision and accuracy of reported results.

The extent of contamination at RMA shown in this report is largely dependent on CRLs of laboratories used for water quality analysis. CRLs for methods certified under the USATHAMA Quality Assurance Program are inherently different for each laboratory instrument. Method efficiency is also dependent on the analyst proficiency in preparing calibration standards. CRLs developed using USATHAMA methodologies are designed to provide the most accurate and reliable data possible. Method development, improved instrument efficiency, and new analytical techniques have contributed most significantly to changes in CRLs.

For the Task 44, TMP, and CMP data sets, analytical uncertainty is also created by the use of the ">" ("greater than") qualifiers when concentrations are greater than the upper limit of the certified reporting range (Table 5.1-1). "Greater than" values represent an underestimate of the true analyte concentration; however, this effect is more pronounced as the actual analyte concentration increases relative to the upper limit of the certified reporting range. The uncertainty of analytical comparisons is further complicated in the assessment of data for analyte groups such as volatile organic compounds. In this case the analytical uncertainty may have been introduced by a single analyte but the qualifier is applied to the entire group.

In the case of volatile aromatic compounds, several values were recorded as greater than a concentration but concentrations were within the certified reporting range of the method. There are several possibilities to explain why these values are qualified as "greater than" results:

1. Data reporting or data entry error has occurred;
2. Matrix interferences or overlapping peaks on the gas chromatograph may have forced the analyst to impose his best judgment concerning the peak area attributable to the compound of interest; and

3. Sample dilutions and the use of dilution factors may have been necessary to bring a primary sample constituent into the working range of the instrument, thus elevating method CRLs by a factor equivalent to the dilution factor.

In all of these cases, except those involving reporting errors, "greater than" qualified values must be considered indicators that at least the specified amount of the analyte reported is present in the investigative sample. The exact quantity present in the investigative sample, however, cannot be further defined.

5.2 Potentiometric Data Assessment

Potentiometric data collected during three quarters of FY88 are discussed in the context of geologic and hydraulic controls that affect RMA ground water flow. These controls are both natural and man-made.

5.2.1 Geologic Controls

As discussed in Section 2.0, the two operative ground-water flow systems at RMA are the unconfined flow system and the confined flow system. The general slope of the water table and the associated direction of ground water flow in the unconfined flow system is northwest toward the South Platte River.

The configuration of the bedrock surface exerts a strong geologic control on the water table surface. In areas like Sections 23 and 24 where the bedrock surface is relatively flat, the water table mimics the bedrock surface and is itself relatively flat. In other areas such as the western portions of Sections 2, 35 and 26, a steepened bedrock surface is mimicked by a steepened water table hydraulic gradient. Although many factors other than bedrock surface morphology can effect changes in the water table surface, the two examples cited above illustrate what is considered to be a major factor controlling water table configuration.

The confined flow system at RMA has been subdivided into numerous stratigraphic zones. Because these zones were designated primarily on the basis of geologic information, zone designations in localized areas may be inadequate to describe observed patterns of ground-water flow. For example, potentiometric data obtained from Well 02044, northwest of South Plants, does not appear to fit the geologic zone designations as presently defined. In this well the water level is 22 ft below the potentiometric surface in zone A, but is 18 ft above the surface in the vertically adjacent

zone 1U. Stratigraphically, the monitored interval in Well 02044 has been assigned to zone A, but its anomalous water level illustrates that the geologic zone descriptions may not always be effective in characterizing ground-water flow in the confined flow system.

The confined flow system operates under a considerably more complex hydrodynamic regime. Varying degrees of confinement are observed within individual zones, particularly in the vicinity of subcrops. In addition, different zones exhibit different potentiometric surface configurations. The general direction of flow in stratigraphic zones of the unconfined flow system is northwest and north. At or near the subcrop, each zone of the confined flow system has a potentiometric surface which is equal to the water table. This indicates that the conditions within these zones gradually change from confined to unconfined.

5.2.2 Hydraulic Controls

Hydraulic controls impacting RMA potentiometric conditions include sources of recharge and discharge, some natural and some man-made. There are numerous sources of ground-water recharge at RMA, including: the Lower Lakes (Mary, Ladora, Upper and Lower Derby, Havana Ponds), First Creek, Sand Creek Lateral and various ditches and canals. These sources of surface recharge at RMA have a much greater impact on water-table conditions in the unconfined flow system than on potentiometric surface conditions in the confined flow system.

The boundary containment systems (Irondale Containment System, Northwest Boundary Containment System and North Boundary Containment System) are sources of both ground-water discharge and recharge. The impacts of these systems on potentiometric conditions appear limited to the unconfined flow system within which they operate. This is shown by clearly offset water table contour lines crossing the systems (Figures 4.1-1 through 4.1-3). Ground-water pumpage attributable to the Irondale Containment System, Northwest Boundary Containment System, and North Boundary Containment System has caused changes in the RMA potentiometric surface. Effects of discharge at the Northwest Boundary Containment System can be seen in Figures 4.1-1 through 4.1-3, where a closed depression can be attributed to pumpage.

Of particular significance to potentiometric data assessments that will be made in the future, are the recharge capacity modifications that have been incorporated into the operation of the North Boundary Containment System. With increased recharge capacity, it is anticipated that the head differential across the North Boundary Containment System will diminish. The addition of recharge trenches to the North Boundary Containment System operation is not expressed in the

water-table maps presented in this report. The recharge trenches were installed after the 1988 CMP monitoring was completed.

First Creek may serve as either a discharge or recharge source depending on location and stream stage. In upstream reaches of First Creek during wet periods of the year, First Creek has been found to be a recharge source. Downgradient of the North Boundary Containment System ground water provides baseflow to First Creek. These assessments were made based on seasonal variations in surface-water flow. Potentiometric data presented in Section 4.0 do not clearly show the relationships described above, due to the scale of the maps and the contour interval that was used.

Vertical hydraulic gradients between unconfined and confined flow systems and between vertically adjacent zones of the confined flow system generally are downward. This indicates a potential for downward ground-water flow. Downward flow is particularly significant in contaminated areas, especially if vertical flow is enhanced by fractures, stratigraphic pinchouts of confining beds, or improperly sealed wells. The lateral is the primary flow component.

5.3 Contamination Assessment

This section provides an assessment of the contaminant hydrogeology of RMA including a summary of contaminant sources, the extent of contamination, contaminant migration from source areas, and the efficacy of the currently operating boundary control systems. This report completes the first of a long-term CMP effort. The intent of this chapter was to build on the contamination assessment presented in the Water Remedial Investigation Report (Ebasco, 1989).

5.3.1 Sources of Contamination

Sources of contamination at RMA have been reported in various work products, including Contamination Assessment Reports and the Study Area Reports generated under the Remedial Investigation/Feasibility Study (RI/FS) program. As a result of RI/FS investigations, source areas were given designations as confirmed or suspected.

The South Plants Area encompasses an area of approximately two-thirds of a square mile and contains numerous sources resulting from industrial operations, waste disposal activities and spills. This information coupled with the fact that this area has significant levels of documented ground-water contamination warranted the designation as a confirmed source area.

The Basin A area (Section 36) received large volumes of waste water from South Plants and North Plants operations. The Basin A area was also used for trench disposal of industrial by-products, off-spec materials, and munitions. Documented ground-water contamination emanating from the Basin A area also warranted the confirmed source area designation for this site.

From 1956 to 1978 waste water was discharged to asphalt lined Basin F. The collective discharge of industrial waste waters and the waste handling activities in the Basin F area, coupled with documented ground-water contaminant plumes, yielded a confirmed source area designation for the Basin F Area. Contaminant distribution is complicated in this area by the sanitary sewer, the operation of surface facilities supporting the deep well operation and the leakage of chemicals from chemical sewers.

The Railyard Area is the source of a DBCP plume resulting from Railyard handling of this chemical. During the RI/FS program, there was evidence to suggest that within this area, specifically the motor pool and/or roundhouse, were sources which resulted in a ground-water plume of chlorinated hydrocarbons (i.e., TRCLE). Additionally off-post sources of these same chlorinated hydrocarbons were documented although the investigation did not pinpoint this off-post source. For these reasons the Railyard also was considered a confirmed source area.

The chemical sewer system transported aqueous wastes from North Plants and South Plants to the basins. Long sections of the system were constructed of vitreous clay pipe which is known to have leaked. The chemical sewers are a confirmed contaminant source. The "suspected source area" designation was used for sources of ground-water contamination inferred on the basis of known contaminant occurrence. Suspected source areas include Basins B, C, D and E, and Sand Creek Lateral.

Indications of the type and mass of materials disposed of at RMA were provided by Geraghty & Miller (1986). The highest reported volume of waste was attributed to Dieldrin, benzene, chloroform, fluoride and chloride. Moderate levels of waste disposal was reported for Endrin, p-chlorophenylmethyl sulfide and sulfoxide, and for DBCP. Low waste disposal volume was reported for p-chlorophenylmethyl sulfone. Many contaminants were not rated according to the volume of materials contained in disposal wastes. These include: dithiane, oxathiane, benzo-thiazole, chlorobenzene, trichloroethane (TRCLE), tetrachloroethane, arsenic and DIMP. Although the volume of DIMP waste was not rated, it had a history of moderate production at RMA.

5.3.2 Extent of Contamination

The extent of contamination at RMA was assessed from two perspectives. First, the areal extent of contaminants was assessed for the unconfined flow system. Second, the vertical extent of contamination was assessed.

5.3.2.1 Extent of Contamination in the Unconfined Flow System. Well defined plumes of ground-water contamination in the unconfined flow system originate from source areas and extend in some cases for several miles. The ground-water plumes of greatest magnitude and concern originate from: (1) the Railyard from which they migrate northward, where they are intersected by the Irondale Containment System (ICS); and (2) the Basin A/South Plants Areas from which they travel northwest to the vicinity of Basin F, where additional contaminant loading is interpreted to occur. From here this plume bifurcates as a result of hydrogeologic conditions and extends toward both the north and the northwest boundaries to be intersected by the North Boundary Containment System and Northwest Boundary Containment System. Most of the primary flowpaths in the unconfined flow system can be directly related to the presence and orientation of permeable material.

The impact of remedial systems on the extent of contamination is generally limited to the unconfined flow system. An exception to this is at the North Boundary Containment System where some remediation of the unconfined flow system was attempted. In this area, ground-water pumping from the confined flow system may have been inducing downward contaminant migration from the unconfined flow system. As a result, pumping from the confined flow system was discontinued. In the unconfined flow system, however, the impact of the RMA remedial systems is clearly shown. At the North Boundary Containment System, most contaminants spread laterally along the southern side of the system, with downgradient plumes that are more narrow, as illustrated by TRCLE, TCLEE, DIMP, DBCP and DCPD. At the Northwest Boundary Containment System, a number of contaminants for which the system was not originally designed flow south of the system and extend to the off-post area. These include chlorobenzene, chloroform, summed VOHs, summed VOAs, TRCLE, fluoride, arsenic and chloride. This system was installed to remediate DBCP, as information on the distribution of other contaminants to the South was not available at that time. The extent of the DIMP and DBCP plumes is controlled by the Northwest Boundary Containment System and does not extend to the off-post area.

The distribution of contaminants for each of the 18 target analytes or contaminant groups that are the focus of this assessment is discussed in Section 4.0. To better understand the contributions of contaminants to the RMA environment and their transport in the environment, the areal extent

of contamination at RMA is viewed here from two perspectives. First, contamination extent associated with source areas is considered. Second, contamination extending into the off-post area is investigated to assess the need for remediation in these areas, and the efficacy of existing remedial systems. For both assessments, it is necessary to consider both unconfined and confined flow systems so that a three-dimensional evaluation of contamination is provided.

As stated previously, most contamination at RMA is associated with the South Plants area, Basin A area and Basin F area. It is generally difficult to assess the contribution of the South Plants alone, because Basin A contributes most of the same contaminants to the environment. Therefore the following discussion combines these primary source areas.

5.3.2.1.1 South Plants/Basin A Area. - Contamination originating in the South Plants alone, or the South Plants with additional contributions from Basin A, generally extends a maximum 5,500 to 6,500 ft downgradient of the South Plants in the unconfined flow system. Exceptions to this include Dieldrin, composited volatile organohalogenes, fluoride, chloride and arsenic, all of which extend to the off-post area; and DBCP which extends about 15,000 ft northwest from the South Plants.

Some contaminants emanating from the South Plants exhibit radial transport away from the ground-water mound in the area. However, the predominant flow direction from the South Plants north and northwest in the same direction as the regional ground-water flow. Contaminant migration to the South has been limited to a maximum of about 2,000 ft for volatile organohalogenes, and to 1,000 ft for other organics such as benzene and DCPD. Inorganic contaminants have migrated as far as the more mobile organic contaminants.

Contamination of the confined flow system is primarily attributable to enhanced vertical migration associated with stratigraphic pinchouts, fractures, faults or improperly sealed wells. Contamination of the confined flow system that may clearly be associated with the South Plants or Basin A is interpreted to be limited to zones A, VC, IU and I. An illustration of the downward component of contaminant migration is illustrated by benzothiazole in the Basin A Neck. High concentrations in the unconfined flow system in this area may be associated with contaminants in the confined flow system. Contamination in the vicinity of South Plants/Basin A travels vertically down in the stratigraphic section, and laterally to the Northwest in response to the regional hydraulic gradient. Contaminants return to the unconfined flow system in the Basin A Neck where sandstone subcrops. The mechanism for vertical migration is not known at present. It is not possible at this time to definitively define the extent of contamination associated with South Plants in the vertical direction due to the paucity of recent water-quality data for the South Plants Area.

5.3.2.1.2 Basin F. - The Basin F area included the deep well and support system facilities, the chemical sewer, the Basin F impoundment and the sanitary sewer. Construction of Basin F, an asphalt-lined reservoir, was completed in December 1956. The capacity of the basin was 240,000,000 gallons. Basin F received wastes from 1956 through 1981. The deep well and support facilities handled wastes from 1962 through 1966. The deep well and facilities were closed in 1985. The chemical sewer was constructed to deliver waste to Basin F, was operated from 1956 to 1981 and was removed in 1982. The sanitary sewer has been in operation since 1943 and is operational at the present time.

Numerous, significant contaminant plumes in the unconfined flow system extend at least 6,500 ft from the Basin F area to the North Boundary Containment System and continue off-post. Remnants of contaminant plumes downgradient of the North Boundary Containment System extend an average maximum distance of 6,000 to 9,000 ft off-post. It is likely that most of the contamination in the off-post area is the result of contaminants that were present in ground water and soil prior to operation of the North Boundary Containment System. Assessments of the system indicated that minor contributions of contaminants are currently being provided to the unconfined system by either subcropping Denver Formation sands, or by flow bypassing the North Boundary Containment System in limited quantities in the vicinity of the pilot system. Contamination interpreted to originate in the Basin F area includes all the contaminants discussed in Section 4.0, with the exception of TRCLE.

Contamination of stratigraphic zones within the confined flow system in the Basin F area has been observed in zones 2, 3, 4 and 5. Contamination of the confined flow system in the off-post area extends up to 2,200 ft off-post in zone 4. The assessment of contamination extent is limited by the well control in off-post areas of the confined flow system.

5.3.2.1.3 Western Tier. - Contaminant plumes in the Western Tier are associated with contamination entering RMA from an off-post source as well as source(s) in the Motor Pool/Railyard. The distribution of TRCLE indicates the presence of multiple sources. TRCLE originating from the Motor Pool Area extends off-post, although limited data make it difficult to quantify the off-post extent of the plume. Other contaminants associated with the Railyard extend about 100 to 8,400 ft to the Northwest. Monitoring wells in the confined flow system are limited in number. Only two monitoring wells, both located in zone 5 northwest of the Railyard, were monitored during this year of the CMP. Contamination by VOAs was detected in one well near the RMA boundary.

5.3.2.1.4 North Plants. - Contamination associated with North Plants is limited to DIMP, volatile organohalogenes and fluoride. Based upon data collected in the spring 1988 semiannual monitoring event from newly installed wells, the plume is limited to the immediate vicinity of North Plants. No wells in the confined flow system were monitored in the vicinity of the DIMP plume.

5.3.2.1.5 Sand Creek Lateral. - Contamination probably originating in the South Plants area and transported via the Sand Creek Lateral is indicated on a number of plume maps in the unconfined flow system. Contaminants of concern include dieldrin, summed VOHs and chloroform. Chloroform and the summed group of VOHs show contamination that extends to the off-post area, while contamination by dieldrin extends about 7,300 ft to the Northwest. Contamination in the confined flow system associated with Sand Creek Lateral is assessed using data from three wells, one each in zones 1U, 2 and 3. Only one of these wells, in zone 3, Section 34, is contaminated. It is possible that this contamination is associated with sources within South Plants. Because contaminant migration in the confined flow system is incompletely understood, the source cannot be defined at this time.

5.3.2.2 Vertical Extent of Contamination. In order to assess the nature and extent of contamination emanating from sources at RMA, it is necessary to consider vertical as well as areal extent of contamination. An assessment of the vertical extent of contamination at RMA was undertaken in order to fulfill the following objectives of the CMP:

- To assess the nature and extent of RMA-related contamination in order to maintain and enhance the existing Remedial Investigation database.
- To assess the concentrations of contaminants at depth; these data may then be used to assess the need for, and magnitude of, any ground-water remediation that may be required at RMA. Site-specific remedial design data needs were, however, not addressed in this assessment as it is beyond the scope of the CMP.

Data used to assess the vertical extent of contamination were derived from monitoring programs from the Initial Screening Program through the FY88 monitoring periods of the CMP. Data from several monitoring periods were used in order that the reproducibility and associated reliability of the data could be assessed. The vertical extent of contamination for this assessment was made considering all detections of synthetic organic compounds and arsenic above CRLs, and considering detections of fluoride and chloride above assumed background concentrations (1,720 $\mu\text{g/l}$ and 62,600 $\mu\text{g/l}$, respectively).

The general approach in this assessment was, where possible, to identify the deepest contamination in each on-post section, then to associate the observed contamination with known source areas. Because the mechanisms controlling contaminant migration, particularly in the confined flow system, are not understood in detail, suggested source/contaminant relationships should be considered preliminary. Second, contaminant concentrations at depth were assessed on the basis of the analytes presented in Section 4.3. For each analyte, the deepest CMP detection was identified. If this detection was unconfirmed, the deepest confirmed detection during all monitoring periods under consideration was identified. The results of this evaluation of contamination at depth are presented below. First, the areal distribution of deep contamination by organic compounds is presented. Second, the areal distribution is assessed for three inorganic species: arsenic, chloride and fluoride. Finally, the maximum depth of each of the CMP analytes presented in Section 4.3 is identified.

5.3.2.2.1 Vertical Extent of Organic Contamination. - The maximum vertical extent of organic contamination was identified for the on-post RMA area on a section-by-section basis in order to make a preliminary assessment regarding the possible sources of the observed contamination (Table 5.3-1).

The South Plants source area is the most probable point of origin for contamination in Sections 1 and 2. The maximum depth of contamination in the current assessment, 73 ft, is in contrast to the maximum depth of 210 ft in Well 01048 reported in the Water Remedial Investigation Report. Because data from this well mentioned in the Water Remedial Investigation Report were not confirmed with previous or subsequent data, they were considered anomalous.

The deepest confirmed detection of organic compounds in Section 3 is in the unconfined flow system, in Well 03523. The monitored interval for this well is 53 to 73 ft. The source of contamination in this well is the Railyard.

The likely sources of deepest organic contamination in several sections of RMA, including Sections 23, 24 and 26 (Table 5.3-1), are Basins C, D, E and F and/or chemical and sanitary sewers and deep, well facilities. The relationship of contamination in the wells identified in Table 5.3-1 to the Basin F area is most clear for Sections 23 and 24. In contrast, based on the location of Well 26142, it appears possible that the origin of observed contaminants could have been Basin C or the sewer systems. The depth of contamination in the wells in these sections is in the range of 100 to 150 feet.

In the vicinity of the North Plants, Section 25, the deepest contamination detected was in Well 25018. The contamination in this well has not been confirmed because only one round of sampling has been conducted in the well to date. The results from this well, if confirmed, would indicate that the maximum depth of organic contamination identified to date is within alluvium in the 23 to 43 ft depth interval, and is probably the result of contamination from the North Plants area.

The Basin A area appears to be the likely source of contamination found at depth in Sections 27, 35 and 36. However, the proximity of other potential sources complicates this assessment. For example, the deepest contamination in Section 27, within the 90 to 105 ft monitored interval in Well 27054 (Table 5.3-1), may emanate from the Basin A. However, the proximity of the well to Basins C, D and E suggests that these could be the origin of the contaminants. Contaminants detected in Well 35066, due to its location, are attributed to Basin A. Contaminants in Well 36110 likely are the result of contamination from Basin A, but based upon the well's location, it is also possible that the contaminant source was the South Plants.

Contamination at depth that is not clearly related to the major RMA source areas discussed above exists in several sections of RMA. These include contamination identified in Table 5.3-1, in Sections 4, 7, 9, 28, 30, 33 and 34.

Contamination in Section 4 represents the highest concentrations of deep contaminants identified in Table 5.3-1. Analytes have been detected in Well 04009 at depths of 145 to 155 ft. The source of the contaminants is not known but may be related to RMA sources in Section 4, such as the Motor Pool area. It is also possible that the contamination is the result of fuel service stations just outside the RMA boundary.

Low concentrations of benzene have been detected repeatedly at depths of 129 to 139 ft in Well 07005 located in Section 7. This well is located upgradient of identified RMA and off-post sources.

Organic compounds have been detected at depths of 52 to 77 ft in Section 9. It is likely that the source of these compounds is located off-post.

The deepest confirmed organic contamination in Section 28 is in Well 28027 at depths of 39 to 48 ft, which is an unconfined flow system well. Based upon the migration pathways identified in the unconfined flow system (Section 2.0), it is possible that this contamination may emanate from the South Plants area, from the western section of the RMA sanitary sewer system, from the Sand Creek Lateral, or from off-post sources south of RMA.

Contamination observed at depths of 123 to 133 ft in Section 30 was not detected during the Water Remedial Investigation and is not closely associated with major RMA source areas. Continued monitoring at this well will provide data necessary to confirm this contamination. This conclusion is based upon the location of Well 30011 adjacent to and east of First Creek and upgradient or cross gradient from known RMA source areas.

The deepest contamination observed in Section 33 was in Well 33032 at depths of 190 to 200 ft. This represents the deepest confirmed contaminant detection at RMA. The source of the benzene in this well is not known, but may be related to the Railyard, Sand Creek Lateral, South Plants, or upgradient off-post sources.

The deepest organic contamination in Section 34 was in Well 34008 at depths of 55 to 85 ft. This well is completed in alluvial sediments. The likely source area for this contamination is Sand Creek Lateral.

5.3.2.2.2 Vertical Extent of Inorganic Contamination. - The assessment of the vertical extent of inorganic species is limited to fluoride, chloride and arsenic. Fluoride and chloride were considered if detected above assumed background concentrations. Arsenic was considered if detected above its CMP CRL value (3.07 ug/l). Background concentrations of fluoride and chloride were assumed to be 1,720 and 62,600 ug/l, respectively.

Table 5.3-2 lists the deepest detections of inorganics, by section, for the RMA on-post area. No attempt was made to relate the observed contamination to particular RMA source areas because the inorganics are commonly associated with numerous RMA source areas. Therefore, the primary utility of the data in Table 5.3-2 is to assess the vertical extent of inorganics.

5.3.2.2.3 Vertical Extent of Specific Analytes. - The vertical extent of individual analytes identified in Section 4.3 were identified to assess whether particular contaminant groups appear to be consistently associated with the deepest migration. Table 5.3-3 shows the maximum observed depth of each analyte that was confirmed in at least two monitoring periods from the Initial Screening Program through FY88 of the CMP. Review of Table 5.3-3 indicates that the deepest contamination, in the depth range of 150 to 200 ft, is generally associated with inorganics. The only organic compound that was detected in this depth range was benzene. The depth ranges associated with the remaining organic contaminants in Table 5.3-3 show no clear relationship between contaminant groups and the maximum depth at which compounds are detected.

5.3.3 Transport and Fate of Contaminants

5.3.3.1 Physical and Chemical Properties Affecting Contaminant Mobility. The rate of contaminant transport in the RMA ground-water environment is controlled by the physical and chemical properties of each contaminant, the properties of the transport medium, and the ground-water flow regime. Patterns of ground-water flow have been discussed previously. This section provides a brief discussion of the properties of the contaminants and the aquifer system that controls contaminant transport. A more detailed discussion of how properties of contaminants and the aquifer affect contaminant mobility can be found in the Task 23 Report (ESE, 1988e) and Reports for the Endangerment Assessment (Ebasco, 1988a & b).

Physical properties which affect contaminant mobility include physical state, specific gravity or density, vapor pressure (volatility), molecular weight and aqueous solubility. Properties of RMA target compounds have been tabulated under the Task 35 Endangerment Assessment and in the RMA Chemical Index (Geraghty and Miller, 1986). Physicochemical properties of select RMA contaminants are presented in Table 5.3-4. Chemical processes that affect contaminant mobility include the partitioning of the contaminant between aquifer material and water, chemical transformation, biodegradation and chemical degradation. Although a significant amount of information is available on the physical properties of RMA target compounds, very little information is available to estimate rates of contaminant degradation or transformation. A sufficient amount of data on octanol/water partition coefficients is available to estimate partition coefficients for the RMA ground-water system. The resultant values are subject to error, but can be used to develop estimates for retardation factors (Rf) accurate within an order of magnitude.

In general, contaminants in ground water at RMA are transported in a dissolved state. At several RMA source areas it is possible that free organic phase liquids are present in the saturated zone. The presence of such organic contamination, if it exists, should not alter regional contaminant transport mechanisms, but would act as a subsurface contaminant source.

The density (specific gravity) of a specific RMA contaminant will not greatly affect regional contaminant transport in an aqueous medium, and stratification of dissolved constituents due to density differences generally has not been observed. The only instance in which density of a contaminant or contaminant mixture would affect transport is when free organic phase liquids are present in the unsaturated or saturated zone.

The physical property which most strongly controls the concentration of a contaminant released from a source area is aqueous solubility. Solubility is the maximum concentration that can be

present in solution. Factors which influence solubility include temperature, dissolved solids, pH (primarily for inorganic constituents), and dissolved inorganic matter. Many of the organic RMA contaminants (purgeable halocarbons and aromatics) have solubilities approaching or exceeding 1,000 mg/l, which is considered very soluble by environmental standards. Solubilities of inorganic ions (chloride and fluoride) are typically high and once present in a dissolved state are not readily removed from solution.

Vapor pressure is a physical property which controls the volatilization of dissolved contaminants from the RMA ground-water system to the vapor phase of the unsaturated zone. The Henry's Law Constant (H) for a specific contaminant relates (at equilibrium) the concentration of the contaminant in water to the concentration present in the vapor phase. This constant allows prediction of the loss of volatile components from ground water.

Considerable effort has been made to tabulate octanol/water partition coefficients (K_{ow}) and distribution coefficients (Kd) for RMA contaminants as found in publicly available literature (Task 35 Toxicity Assessment Report). In addition, Task 23 performed site-specific tests to measure in situ Kd values for key RMA contaminants. This program concluded that for organic contaminants, partitioning was primarily controlled by the concentration of organic matter in the aquifer material, and that measured values, when available, fell within the range of Kd values present in the literature. The range of Kd values present in the literature for key RMA contaminants commonly varies over two to four orders of magnitude. As a result, it is difficult to predict contaminant partitioning and equally difficult to select a representative retardation factor (Rf). Such variabilities in Rf values result in a wide range of potential rates for contaminant transport.

Data on processes of biodegradation, chemical degradation and chemical transformation of RMA contaminants are not available, and therefore, consideration of these processes in the estimation of contaminant transport is not possible. These processes, which would all tend to reduce solute concentrations, have not been considered as factors contributing to contaminant attenuation. It should be emphasized that estimates of contaminant transport that do not consider these processes would tend to overestimate contaminant concentrations occurring downgradient of a particular source.

5.3.4 Rates of Contaminant Transport

In this section, comparisons are made between estimates of travel distance based on ground-water flow velocities and directions with the distances and extent of observed contaminant transport. From these data, retardation factors (Rf) are estimated and compared with values existing in the

literature. Factors of importance in these assessments are hydraulic conductivity, chemical retardation, estimates of ground-water flow velocities and directions, and contaminant transport pathways and migration velocities. From best estimates of hydraulic conductivity, observed hydraulic gradients, and assumed effective porosities, ground-water flow velocities were calculated for various locations within the study area. These velocities ranged from approximately 10 ft/yr in areas where the unconfined flow system consists of Denver Formation (unsaturated alluvium) to as high as 10,000 ft/yr in some areas off-post northwest of RMA.

As part of the Water Remedial Investigation (Ebasco, 1989), the unconfined flow system was divided into hydrogeologic units. Aquifer tests within each hydrogeologic unit were used to estimate typical values and expected ranges of hydraulic conductivity. These estimates of hydraulic conductivity are shown in Figure 5.3-1.

In this section, ground-water velocities along the Basin A Neck and Basin F North/North Off-post Pathways were estimated by Darcy's Law using: (1) minimum hydraulic conductivity (K) values; (2) best estimate K values; and (3) maximum K values (Figure 5.3-1). An assumed value of 0.20 was used for effective porosity in all calculations. From the resulting ranges and distributions of velocities, 30-year travel distances from source areas (Basins A, C and F) were estimated along each pathway (Figure 5.3-2 and Table 5.3-5).

For the Basin F North/North Off-post Pathway, the minimum and best estimate hydraulic conductivity values yield 30-year travel distances that are lower than the migration distances observed for conservative analytes such as DIMP. However, the maximum hydraulic conductivity values predict that ground-water originating at the source areas would reach the South Platte River in 18 years. Therefore, hydraulic conductivities between the best estimate and maximum values in this portion of the unconfined flow system provide closer agreement with observed chemical data.

Along the Basin A Neck Pathway, even minimum values of hydraulic conductivity allow ground water from Basin C to reach the South Platte River within 30 years. For flow from mid-Basin A, the minimum hydraulic conductivity value allows ground water to reach point A on Figure 5.3-2 within 30 years or less. While transport of ground water originating from Basin C to the river within this time period is likely, chemical data suggest that a shorter travel distance is more plausible. Therefore, in the Basin A Neck Pathway, chemical evidence suggests that hydraulic conductivities should be closer to (and possibly less than) the minimum values estimated along this pathway.

Apparent migration velocities (Table 5.3-6) were estimated for various chemical contaminants. These estimates were made along several pathway by dividing observed distance a contaminant has migrated from its source and dividing it by the amount of time the source area has been active. Reasons that apparent migration velocities may not equal actual ground-water velocities are as follows:

1. Average migration velocity may not account for variations in hydraulic properties occurring along the contaminant pathway. Ground-water and migration velocities are proportional to hydraulic conductivity. Because hydraulic conductivity can vary by orders of magnitude in natural geologic media, the presence of low conductivity units, even along a short portion of the pathway, can greatly reduce the computed average velocity.
2. Estimates of the active life of contaminant sources are subject to error. If a specific contaminant was introduced years after the initial use of a source area, the computed contaminant velocity may be unrealistically low.
3. Effects of dilution, dispersion, diffusion, or attenuative geochemical processes are not considered.
4. The time that a contaminant might reside in the vadose zone is not considered. If this time is significant, the method would underestimate the actual migration velocity.
5. Migration distance of a compound is determined by the leading edge of the plume. Dilution of ground water and sparse well control in distant off-post areas may preclude accurately locating the leading edge. In this case, apparent velocity would have a tendency to be underestimated.
6. A portion of the observed contaminant migration may be due to surface-water migration rather than ground-water migration.

As a consequence of these factors, the apparent velocity estimates in Table 5.3-6 should be considered minimum values for contaminant migration.

For the pathways described above, the apparent contaminant migration velocities for selected contaminants range from 50 to 530 ft/yr for Basin A Neck Pathway, and from 230 to 870 ft/yr

for the Basin F North/North Off-post Pathway. Considering the larger velocities to be representative of conservative analytes, the apparent contaminant migration velocities of 530 and 870 ft/yr are comparable to computed average ground-water velocities of 600 ft/yr in Basin A Neck Pathway (minimum hydraulic conductivity) and 530 ft/yr in Basin F North/North Off-post Pathway (best estimate hydraulic conductivity), respectively. This analysis provides relatively good agreement between the two methods. However, the results suggest that hydraulic conductivity in the Basin A Neck areas is lower than best estimate values developed.

As shown in Table 5.3-6, the ratio of maximum-to-minimum migration velocity for analytes within the various pathways ranges from 1.2 to 10.6. If DCPD and dithiane/oxathiane velocities in the Basin A Neck are not considered, the range in velocity ratios is 1.2 to 3.5. These ratios should also represent the relative variation in retardation factors for the analytes considered. Retardation factors for RMA contaminants are expected to range over several orders of magnitude. Thus, the variation in contaminant migration velocities in Table 5.3-6 is much less than the predicted variation. This implies that observed chemical attenuation of nonconservative species in the unconfined flow system is much less than what chemical theory would predict. The reasons for this discrepancy have not been determined.

5.3.5 Efficacy of Remedial Actions

Remedial systems currently in operation at RMA include the North Boundary Containment System, Northwest Boundary Containment System, and the Irondale Containment System. All are designed to intercept, treat and recharge ground water to inhibit off-site contaminant migration and to begin site cleanup.

The North Boundary Containment System appears to be largely effective in inhibiting off-site contaminant migration. This is shown by the wide distribution of contaminants on the southern side of the North Boundary Containment System and the narrower distribution on the northern side. The wide distribution south of the North Boundary Containment System presumably is caused by lateral spreading or ponding of contaminants along the barrier wall. To the north, the plumes represent primarily remnant contamination that was confined to a narrower region.

Previous investigations (ESE, 1988c) indicated that some water may be flowing through the pilot portion of the North Boundary Containment System as a result of incomplete anchoring of the North Boundary Containment System in bedrock, enhanced communication between the unconfined system, and/or confined Denver Formation sands below the North Boundary Containment System. The enhanced communication may have resulted from increased differences in hydraulic head

across the barrier due to ponding of water to the South and poor recharge efficiency to the north. These problems have since been addressed by installing a number of recharge trenches north of the North Boundary Containment System to spread recharge water more efficiently. Because these measures have been undertaken very recently, it is not yet possible to assess their impact.

The efficacy of the Northwest Boundary Containment System was evaluated by considering its impact on migration of DBCP and DIMP to the off-post area. The Northwest Boundary Containment System was designed to intercept these contaminants. The impact of the Northwest Boundary Containment System on other contaminants at the northwest RMA boundary will be discussed below. As is evident from the plume maps in Figures 4.3-21 and 4.3-24, the system appears to be effective in achieving this goal. Two wells on the downgradient side of the barrier have low concentrations of DIMP, but because DBCP is not consistently observed throughout this area, the system is judged to be effective generally in limiting DBCP transport to the northwest.

Several contaminant plumes, including Endrin and summed VOAs, chlorobenzene, TRCLE and chloroform bypass the southern portion of the system and flow off-post. The northern portions of these plumes do not generally flow past the Northwest Boundary Containment System, but the southern portions generally do, thus allowing contaminant transport to the off-post area. Plumes of both fluoride and chloride do not appear to be affected by the Northwest Boundary Containment System.

The Irondale Containment System was installed to remediate DBCP contamination emanating from the Railyard. The system appears to be effective in achieving this goal, as is evident from the DBCP plume map for spring 1988 (Figure 4.3-22). The spring plume map is more definitive in this assessment than is the winter 1987/88 map, because newly installed wells provided additional monitoring downgradient of the system and confirmed the absence of DBCP in the off-post area. With the exception of TRCLE, migration of other RMA contaminants south of Irondale Containment System area was not observed during CMP monitoring. The TRCLE plume for winter 1987/88 shows that some TRCLE enters RMA from an off-post source to the South, and some emanates from the Motor Pool Area. The plumes from the two sources merge and extend into the off-post area.

Table 5.3-1 Deepest Confirmed Synthetic Organic Compound Contamination
(by Section*)

Section	Well	Depth of Monitored Interval (ft bgl)	Contaminants Detected	Concentration Range ($\mu\text{g/l}$)	Aquifer
1	01036	40-50	CHCl_3 DBCP	9.10-9.11 0.496-0.830	Denver
2	02030	53-73	CCL_4 CHCl_3	4.86-9.53 103-120	Denver
3	03523	63-73	CHCl_3 CL_2CP DBCP	8.54-17.8 0.186-0.327 40.9-54.0	UFS**
4	04009	145-155	CH_2Cl_2 ETC_6H_5 MEC_6H_5 DLDRN XYLENE	20.7-122 11.7-28.3 1.87-4.41 0.064-0.142 33.0-112	Denver
7	07005	129-139	C_6H_6	2.97-4.19	Denver
9	09005	52-77	TCLEE 11-DCLE 12-DCE TRCLE	1.26-2.58 1.28-1.49 6.43-8.48 3.08-6.72	UFS
23	23184	112-117	DLDRN	0.077-0.141	Denver
24	24172 ¹	122-132	C_6H_6 CLC_6H_5	8.18-37.4 29.0-171	Denver
25	25018	23-43	DIMP CHCl_3 TRCLE 111-TCE 11-DCLE	180 18.4 0.996 1.01 1.79	UFS not historically sampled; sampled only during FY88 of CMP
26	26142	138-148	ALDRN DLDRN ENDRN	0.111-6.33 0.571-5.11 0.045-1.56	Denver
27	27054	90-105	TRCLE C_6H_6 MEC_6H_5	1.00-2.76 2.47-4.25 1.26-3.03	Denver
28	28027	39-48	111-TCE	1.12-3.50	UFS

Table 5.3-1 (cont'd.)

Section	Well	Depth of Monitored Interval (ft bgl)	Contaminants Detected	Concentration Range ($\mu\text{g/l}$)	Aquifer
30	30011	123-133	CHCl_3	0.909-20.1	Denver
33	33032	190-200	C_6H_6	1.88-250.0 ²	Denver
34	34008	55-85	DLDRN	0.112-0.143	UFS
35	35066	41-56	DIMP CHCl_3	1400-2100 1.37-1.96	Denver
36	36110	62-65	DLDRN	0.080-0.115	Denver

* All contamination was confirmed in at least two sampling events in the period from the Initial Screening Program through FY88. If the well was used only in the CMP and represented the deepest contamination in the section, the well was listed and the need to confirm data was noted.

** UFS = Unconfined flow system

¹ Previous databases identified this well as 24171.

² Past (pre-CMP) results indicate range of 1.88-3.77.

Table 5.3-2 Deepest Confirmed Contamination by Inorganic Species
(by Section)

Section	Well	Depth of Monitored Interval (ft bgl)	Contaminants Detected	Concentration Range (µg/l)	Aquifer
1	01048	160-210	F	2630	Denver
2	02031	103-138	CL	83,000-100,000	Denver
3	03004	168-178	F	1950 - 4710	Denver
4	04011	153-158	F As	7050-7920 12.5-14.7	Denver Denver
6	06002	25.7-32.7	F	1890	UFS*
9	09003	104-129	F	1820	Denver
11	11004	97.0-105.0	F	2370	Denver
12	12002	19.0-44.0	Cl	91,000-117,000	UFS
19	19015	55.0-75.0	Cl	79,000-87,200	Denver
22	22031	124-134	Cl F	347,000-485,000 1760	Denver Denver
23	23184	112-117	Cl F	477,000-590,000 1740-2280	Denver Denver
24	24120	85.0-95.0	Cl	182,000-200,000	Denver
25	25014	121-136	F	2140-3350	Denver
26	26142	138-146	F	1740-2240	Denver
27	27055	120-135	F As	2100-3210 3.23	Denver Denver
28	28025	92.0-102	F	2420	Denver
30	30011	123-133	F	2420-3130	Denver
33	33032	190-200	F	1940-2080	Denver
34	34003	122-132	F	2100-2810	Denver
35	35039	100-112	F	2100	Denver
36	36114	101.2-146.2	Cl	16,0000-198,000	Denver

* UFS = Unconfined flow system

Table 5.3-3 Deepest Confirmed Detections of CMP Analytes*

Analyte	Well	Depth of Monitored Interval (ft bgl)	Concentration Range (µg/l)	Aquifer
1,1-DCE	33075	57.4 - 77.4	5.55 - 8.09	UFS**
1,1-DCLE	09005	51.5 - 77.0	1.20 - 1.49	UFS
1,1,1-TCE	33077	105.1 - 125.1	0.84 - 1.13	UFS
1,1,2-TCE	02035	31.0 - 46.0	1.07 - 1.22	DENVER
1,2-DCLE	26041	42.9 - 46.9	2.24 - 109	UFS
T-1,2-DCE	04044	49.0 - 69.0	1.15 - 1.85	UFS
CHCL3	30011	123.0 - 133.0	0.909 - 20.1	DENVER
CCL4	02035	31.0 - 46.0	5.55 - 14.7	DENVER
CH2CL2	04009	145.0 - 155.0	20.7 - 122	DENVER
TCLEE	04044	49.0 - 69.0	3.63 - 4.59	UFS
TRCLE	04044	49.0 - 69.0	3.20 - 4.24	UFS
1,3-DMB	04009	145.0 - 155.0	1.02 - 45.1	DENVER
XYLEN	04009	145.0 - 155.0	33.0 - 111	DENVER
C6H6	33032	190.0 - 200.0	1.88 - 250	DENVER
CLC6H5	24171	40.0 - 50.0	21.6 - 170	DENVER
ETC6H5	04009	145.0 - 155.0	11.7 - 28.3	DENVER
MEC6H5	04009	145.0 - 155.0	1.87 - 5.20	DENVER
CPMS	26133	35.0 - 55.0	25.3 - 748	UFS
CPMSO	26129	90.0 - 100.0	10.1 - 11.5	DENVER
CPMSO2	23412	38.0 - 59.4	5.41 - 12.8	UFS
DITH	26129	90.0 - 100.0	22.2 - 89.1	DENVER
OXAT	26129	90.0 - 100.0	9.34 - 12.8	DENVER
DCPD	22024	95.0 - 105.0	10.3 - 21.3	DENVER
DIMP	26129	90.0 - 100.0	214 - 2090	DENVER
DBCP	24168	68.0 - 75.0	0.169 - 0.202	DENVER
DLDRN	24171	40.0 - 50.0	0.090 - 0.091	DENVER
ENDRN	26142	138.0 - 146.0	0.045 - 1.56	DENVER
BTZ	35016	37.0 - 40.4	3.56 - 14.3	DENVER
CL	33032	190.0 - 200.0	1200 - 4800	DENVER
F	33032	190.0 - 200.0	1400 - 2080	DENVER
AS	04011	153.0 - 158.0	12.6 - 14.7	DENVER

* Refers to analytes discussed in Section 4.3 of this report

** Unconfined flow system

Table 5.3-4 Physiochemical Properties of Select RNA Contaminants

Analyte	Solubility (mg/l)	Vapor Pressure (mm Hg)	Rf*	Persistence**	Other
Aldrin	1.39×10^{-4}	3.35×10^{-3} (17°C)	1361	H	Decomposes to Dieldrin
Isodrin	0.16	$<1.0 \times 10^{-4}$	898	H	Intermediate product of Endrin manufacture
Endrin	0.25 (25°C)	2.0×10^{-7} (25°C)	174	H	
Dieldrin	0.16	5.2×10^{-6}	168	H	
M-xylene	130 (25°C)	10 (25°C)	26	L	Solvents associated with Dieldrin and Endrin
o,p-xylene	190 (25°C)	10 (25°C)	26	L	Solvents associated with Dieldrin and Endrin
Dicyclopentadiene (DCPD)	20	1.4 (20°C)	24	M	Raw material in Aldrin and Endrin manufacture
Ethylbenzene (C_6H_5)	160 (20°C)	1.0 (25.9°C)	14	L	
Trichloroethene (TRCLE)	1,100	60 (20°C)	11	H	
Toluene (MEC_6H_5)	520	20 (20°C)	11	M	
Tetrachloroethene (TCLEE)	175 (20°C)	14 (20°C)	10	H	
Chlorobenzene (ClC_6H_5)	448	8.8 (20°C)	9.3	M	
Dibromochloropropane (DBCP)	1,230	0.8 (21°C)	7.0	M	Soil fumigant (nemagon)
Carbon tetrachloride (CCl_4)	800	90 (20°C)	5.5	M	
1,1,1-Trichloroethane (111TCE)	4,400 (20°C)	123 (20°C)	5.0	H	
Chloroform ($CHCl_3$)	7,840	192	3.9	H	
Diisopropylmethyl phosphonate (DIMP)	1,500	0.28 (25°C)	3.8	H	By-product of GB manufacturing
1,1-Dichloroethene (11DCE)	400 (20°C)	500 (20°C)	3.5	M	
Benzothiazole (BTZ)	--	--	3.0		
1,1-Dichloroethane (11DCE)	5,500 (20°C)	180 (20°C)	2.9		

Table 5.3-4 (cont'd.)

Analyte	Solubility (mg/l)	Vapor Pressure (mm Hg)	Rf*	Persistence**	Other
Chlorophenylmethyl sulfide (CPMS)	12	0.11	27	M	
Chlorophenylmethyl sulfoxide (CPMSO)	1,100	5×10^{-4}	2.2	H	
Chlorophenylmethyl sulfone (CPMSO ₂)	1,200	8×10^{-4}	2.5	H	
Benzene (C ₆ H ₆)	1,800 (20°C)	95 (20°C)	2.0	L	Solvent associated with manufacture of Aldrin, Endrin, and Dieldrin
Dithiane	3,000	0.80	1.5		Decomposition product in manufacturing mustard gas
1,2-Dichloroethane (12DCE)	8,690 (20°C)	61 (20°C)	1.4		
Methylene chloride (CH ₂ Cl ₂)	17,000 (20°C)	362 (20°C)	1.4		
Oxathiane	20,000	5.1	1.1		
1,1,2-Trichloroethane (112TCE)	4,500 (20°C)	19 (20°C)		H	

* R = retardation factor based on 30 percent porosity, density = 2.7 g/cm³** L = $t_{1/2}$ < 60 days;M = 60 days $\leq t_{1/2} \leq$ 365 days;H = $t_{1/2}$ > 365 days (Geraghty & Miller, 1986) $t_{1/2}$ = half life

Table 5.3-5 Estimated 30 Year Analyte Migration Distances for Selected Pathways
(in feet)

Compound or Group	Basin A Neck Pathway	Basin F North/North Off-Post Pathway	Western Tier Pathway	Railyard Pathway	North & South Central Pathway
<u>Ground Water</u>					
maximum K*	S. Platte R.	S. Platte R.			
best est. K	S. Platte R.	3900			
minimum K	S. Platte R.	1100			
Chloride	21,000	16,000	---	3,500+	8,000+
DBCP	9,000	16,500	---	9,500	---
DCPD	2,000	8,000	---	---	---
DIMP	7,500	26,000	---	---	---
Dieldrin	11,500	12,000	---	---	7,000
Endrin	9,000	10,000	---	---	---
Dithiane/ Oxathiane	3,200	7,000	---	---	---
Fluoride	21,000	22,000	---	---	7,000
Organosulfurs	6,000	14,000	---	---	---
Volatile Aromatics	12,000	18,000	---	---	---
Volatile Organohalogens	11,000	16,000	15,000	8,000	8,000

* K = hydraulic conductivity

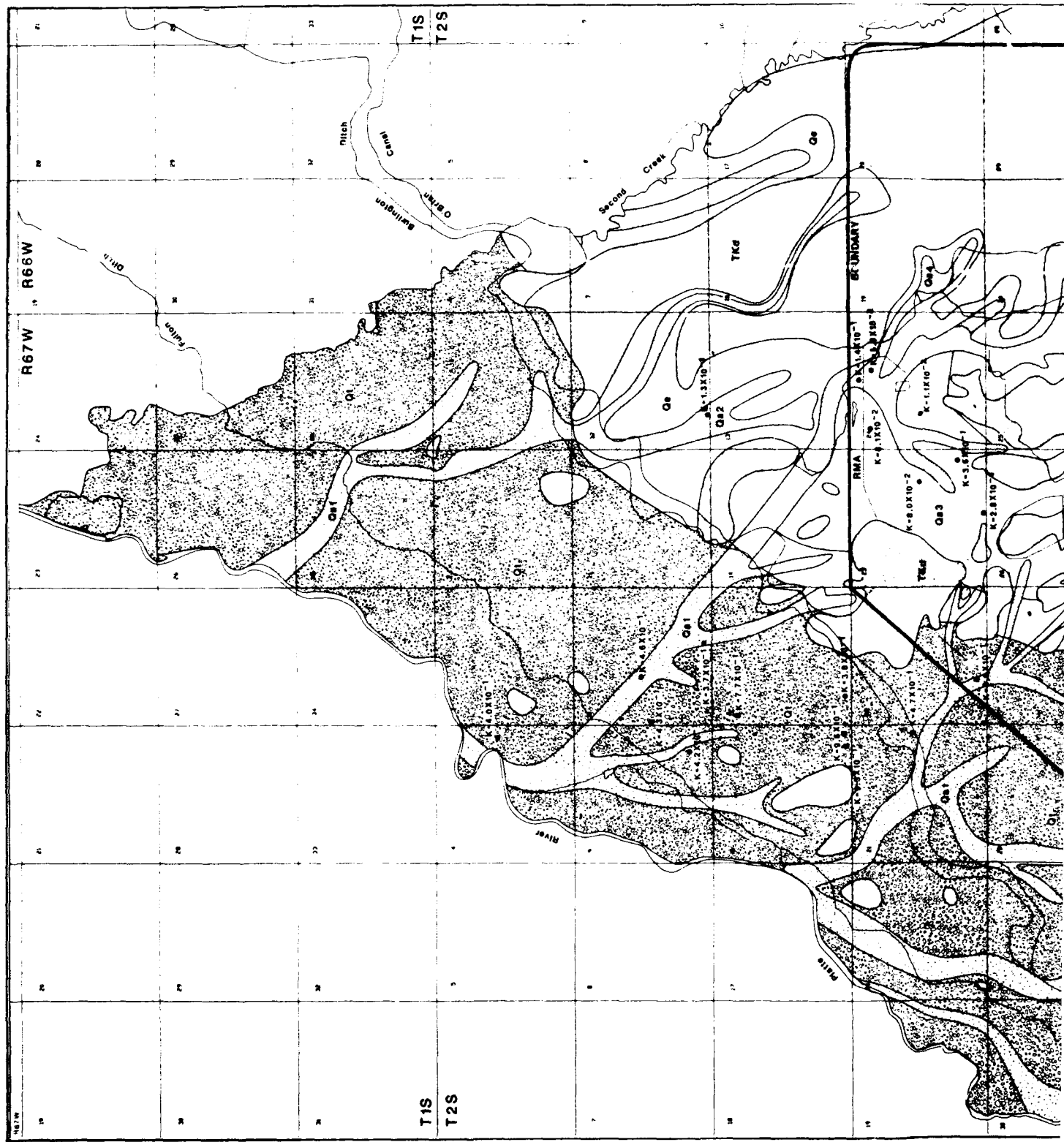
Note: Distance to the South Platte River is approximately 25,000 ft from Basin C and 29,000 ft from Basins A and F.

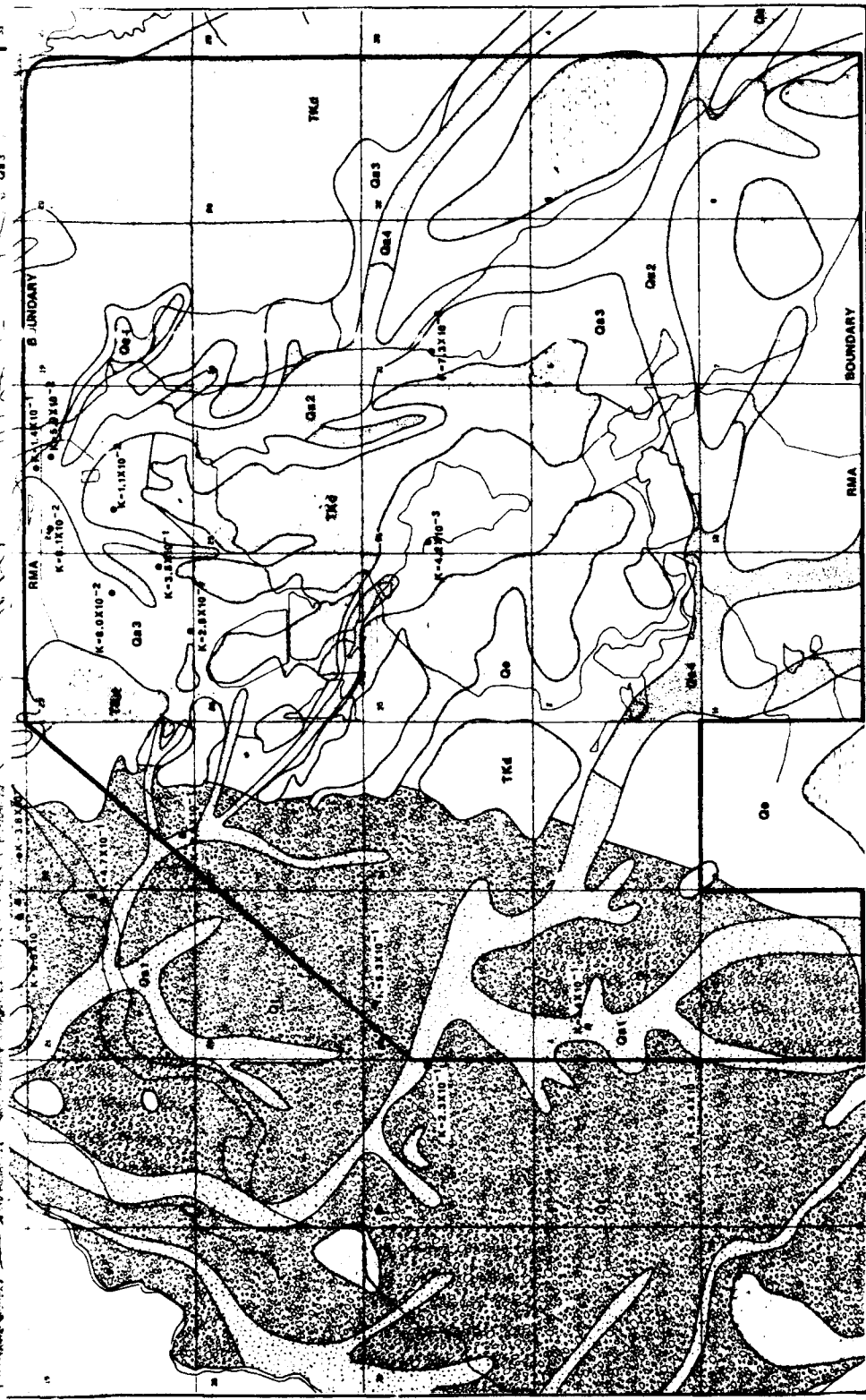
Table 5.3-6 Apparent Average Migration Velocities for Selected Pathways
(ft/yr)

Compound or Group Pathway	Basin A Neck Pathway	Basin F North/North Off-Post Pathway	Western Tier Pathway	Rail Yard Pathway	North & South Central
<u>Ground Water</u>					
maximum K	6,000	1,660			
best est. K	2,500	530			
minimum K	600	170			
Chloride	530	530	---	230+	270
DBCP	230	550	---	630	---
DCPD	50	270	---	---	---
DIMP	190	870	---	---	---
Dieldrin	290	400	---	---	230
Endrin	230	330	---	---	---
Dithiane/ Oxathiane	80	230	---	---	---
Fluoride	530	730	---	---	230
Organosulfurs	150	470	---	---	---
Volatile Aromatics	300	600	---	---	---
Volatile Organohalogenes	280	530	1,000	530	270
F	10.8 3.5*	3.8	---**	(b)	1.2

* DCPD and Dithiane/Oxthiane not considered
** insufficient data

Note: F = ratio of maximum to minimum velocities
K = hydraulic conductivity





EXPLANATION

Contour Interval Equals 10 Feet

Elevations in Feet

Datum Mean Sea Level

Legend: K Values are in cm/sec

Qa3 Silty Terrace Gravel and Coarse Sand
K-8X10⁻² Range-2X10⁻² to 10⁻¹

Qa4 Paleochannels in Eolian
(W/O Gravel) K-5X10⁻² Range-10⁻² to 10⁻¹

Qe Eolian Deposits
K-2X10⁻² Range-4X10⁻² to 4X10⁻³

TKd Denver Fm/Dry Alluvium
K-1X10⁻⁴ Range-10⁻⁵ to 10⁻³

Qa1 Terrace Gravels
K-3X10⁻¹ Range-1X10⁻¹ to 1

Qa2 Paleochannels in Eolian (W/Gravel)
K-1X10⁻¹ Range-5X10⁻² to 5X10⁻¹

• Alluvial Aquifer Pumping Tests

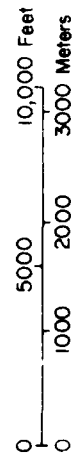


Figure 5.3-1

HYDRAULIC CONDUCTIVITY MAP FOR UNCONFINED FLOW SYSTEM

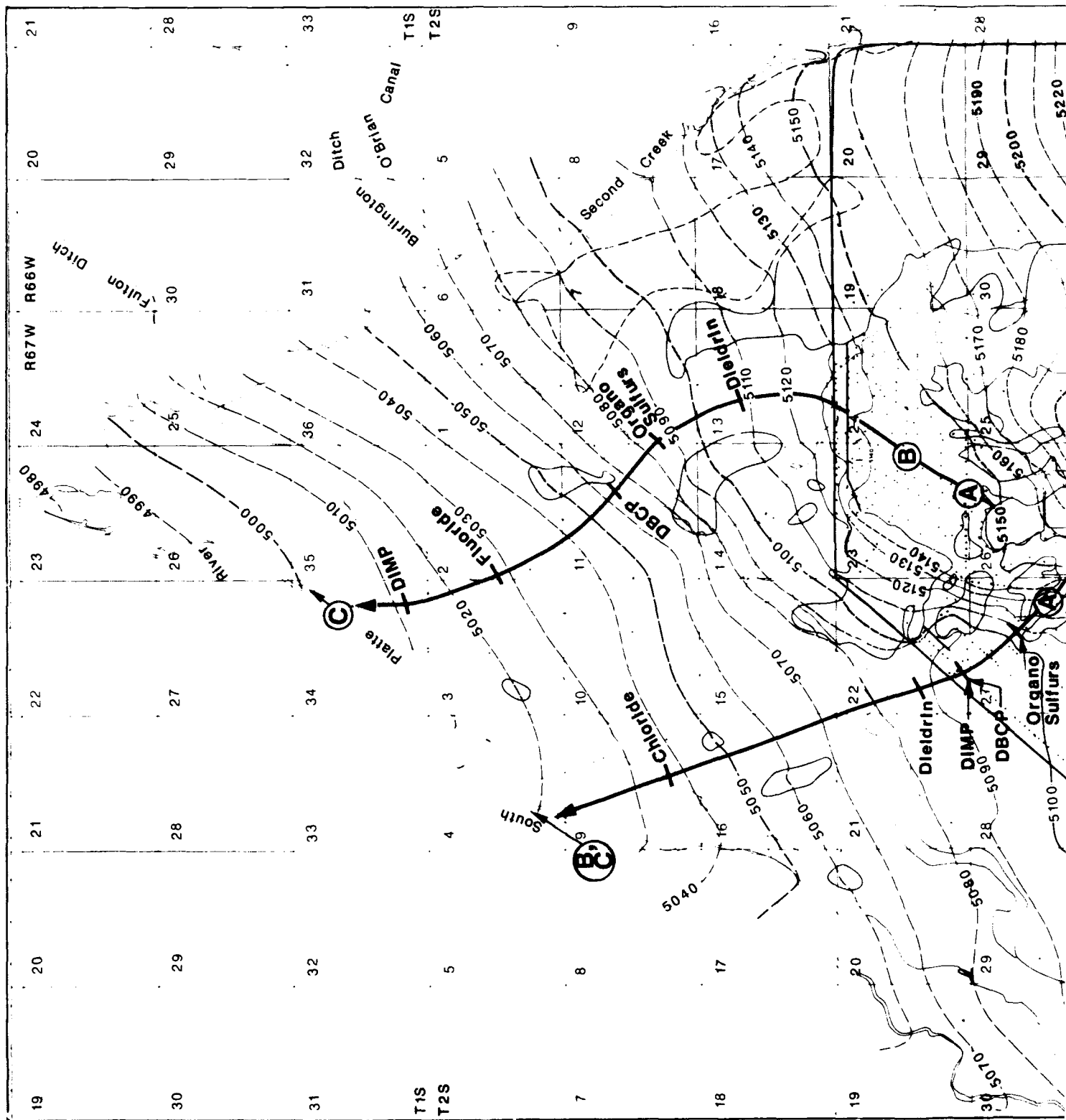
CMP Ground-Water Monitoring Annual Report

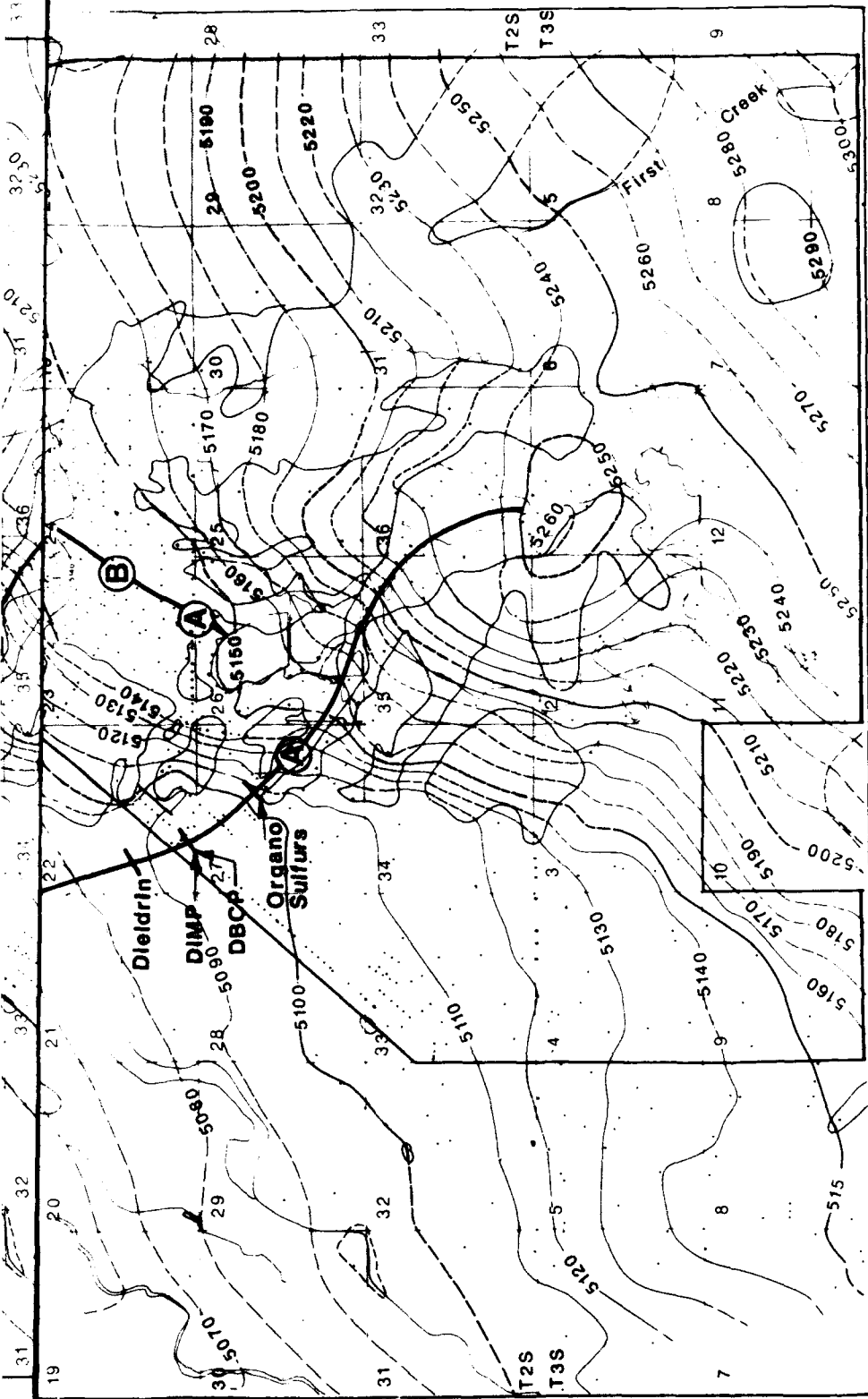
Prepared by : R.L. Stollar and Associates, Inc.

Harding Lawson Associates

Prepared for:
**U.S. Army Program Manager
For Rocky Mountain Arsenal**

Aberdeen Proving Ground, Maryland





EXPLANATION

Contour Interval Equals 10 Feet

Elevations in Feet

Datum Mean Sea Level

Unsaturated Alluvium

Equipotential Contour, dashed where inferred



Migration Pathways

Ground-Water Travel Distance Over 30 Years Using

(A)

(B)

(C)

Minimum K Value

Best Estimate K Value

Maximum K Value

Apparent Plume Extent

Prepared for:

Program Manager's Office for

Rocky Mountain Arsenal

Aberdeen Proving Ground, Maryland

FIGURE 5.3-2

Contaminant Migration Distances in Selected Pathways

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Harding Lawson Associates

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6.0 RECOMMENDATIONS

Based on the results of CMP hydrologic and analytical chemistry data assessments, recommendations are presented below. Some of these recommendations result from field experience and others result from comparisons of CMP data to historical data. These recommendations can be loosely categorized under two headings: analytical program recommendations and sampling and network design recommendations.

6.1 Analytical Program Recommendations

The list of analytical parameters should be modified according to the distribution of contamination at RMA on a section-by-section basis. A single analytical parameter list currently is used for all CMP ground-water samples. The efficiency of the analytical program could be improved by modifying the analytical program to delete analyses for chemicals known to be absent from a given section. Limiting modifications to entire sections would minimize logistical problems associated with using variable analytical suites for ground-water samples. The efficiency of the analytical program would be increased by utilizing a specific analytical parameters list for wells in each RMA section according to the contaminants known to occur in that section.

Two changes to the list of RMA target analytes should be considered for future CMP monitoring. The results of GC/MS analyses indicate that Caprolactam should be added to the target analytes list because it was detected 42 times in these analyses. It is also recommended that vinyl chloride be added to the target list because it is a daughter product known to result from the breakdown of other chlorinated compounds--including trichloroethylene and tetrachloroethylene--that are known to exist at RMA. Because its toxicity is high, presence of vinyl chloride should be monitored to provide further protection of public health and the environment.

Stable isotopes and radioisotopes may be useful in assessing the relationships between water from different aquifer zones and between aquifers and recharge sources. This is possible if the aquifer zones produce water with unique isotopic signatures. To assess the utility of this technique in evaluating geologic, hydrogeologic, and hydrochemical relationships among geologic zones, analyses of stable isotopes and radioisotopes should be conducted on selected ground-water and surface-water samples.

Data assessments presented in Sections 4.0 and 5.0 indicated that lower CRLs are useful in assessing continuity of contaminant plumes between source areas. They are also useful in assessing the directions of contaminant migration at plume margins. Therefore, the CRLs currently employed

for ground-water analyses should be lowered as close as is practicable to the method detection limit, thus aiding the assessment of plume continuity and areal extent of contamination.

Comparisons of CMP analytical data with previous RMA analytical data are complicated by numerous CMP data irregularities. To ensure comparability with previous RMA ground-water investigations, it is recommended that provisions should be made so that data irregularities such as greater than ">" values are not accepted for data use purposes. Presentation of such irregularities diminishes the data utility and impacts meaningful data comparisons.

The lack of ARARs directly impacts the CMP data assessment process. ARARs or guidance levels would provide for more efficient assessment efforts. It is therefore recommended that ARARs or guidance levels be adopted to expedite future assessment efforts.

6.2 Sampling and Network Design Recommendations

The data assessments in Section 5.0 of this report indicate a need to evaluate regionally the lateral and vertical extent of contamination on an analyte-by-analyte basis. Therefore, it is recommended that the CMP annual well network size be increased to ensure that analyte-specific plume configurations can be assessed at a regional scale. The utility of the annual network would be enhanced for assessing localized plume variability. Consequently, the size of the CMP semi-annual network should be decreased overall. Instead of providing monitoring information in nine specific areas, the utility of the semi annual network would increase if more wells were sampled in the specific areas currently undergoing remediation. With an increase in the annual well network and a decrease in the semi annual network, there probably would be no net change in the total number of wells to be sampled. The quarterly monitoring well network would not be affected by changes in the annual or semi annual networks.

Because the presence of Basin F formerly left a large gap in the spatial distribution of Section 26 monitoring wells, it is recommended that new wells be installed in the previous location of the basin. Construction in that area is scheduled to reach final design grade in the summer of 1989.

The CMP assessment of the maximum vertical extent of contamination was hindered by limited monitoring-well control in deep portions of the Denver Formation. For this reason, it is recommended that additional deep well clusters be considered. Optimal cluster locations could be evaluated in the planning stages of a well installation program.

Any free product encountered in monitoring wells should be evaluated more closely as to areal extent, mode and occurrence. Free product is suspected to exist in several monitoring wells located in the South Plants. These wells warrant further investigation.

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